BASIC STUDIES IN SCIENCE

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TEACHER'S GUIDEBOOK

for SCIENCE PROBLEMS

BOOK 1

by

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Preface

The three books of the Science Problems series have been written specifically for science reading and science instruction in the seventh, eighth, and ninth grades of American schools. This Guidebook is intended to assist administrators and teachers in making the most effective use of the series, and specifically of *Book 1*, by stating the authors' point of view on: (1) the objectives of science instruction at this level; (2) the principles and plan of organization of the series; (3) suggestions for fitting the course to local conditions; (4) the general technique of effective instruction in science; and (5) the principal types of difficulties that pupils meet in their study of science.

The *Guidebook* furnishes detailed helps for teaching each unit and includes correct responses for the exercises. These helps are planned especially for the busy teacher, to relieve him of some of the mechanical labor incident to teaching any course and to make clear the authors' aims and method. Neither this nor any teacher's manual can be a panacea for all teaching difficulties, nor should such a manual interfere with the initiative and individuality of the teacher.

The inexperienced teacher will find this *Guidebook* particularly helpful. The experienced teacher will find in it many suggestions which have come out of actual classroom situations. These he will modify and supplement from his own experiences. If the suggestions serve to assist in modifying the lives of pupils through the development of their intellectual powers and through the acquisition of worth-while knowledge, thus insuring that the pupils will better adjust themselves to their environment and control it, the time and effort spent in the preparation of this guide will have been justified. The authors will be most grateful for any suggestions which teachers may wish to offer and which may be included when the Guidebook is revised.

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PART ONE

General Considerations

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1. INTRODUCTION

The formulation of and instruction in a course in science demand that the teacher have a broad vision and a definite concept of the place and function of science in a liberal education. This is particularly true at the seventh-, eighth-, and ninth-grade levels, for here the objectives, content, and method have not as yet been so clearly determined as they have been in the older, more specialized courses for the later years of the high school.

In planning the science course for the early years of the high school or for the last two years of the eight-year elementary school, the administrator and the teacher who conscientiously strive to provide that science instruction which will best serve to educate the coming citizens of their community must consider carefully the following: (1) the valid objectives of science instruction at this level, (2) a plan of organization of the subject matter for effective teaching, and (3) a technique of classroom procedure which will insure the attainment of the objectives sought. The neglect of any one of these steps makes the teaching of science aimless or even harmful.

In order that administrators and teachers may understand thoroughly the plan of the *Science Problems* series, Part One of the *Guidebook* presents general considerations concerning objectives, selection of subject matter, principles of organization, and technique of instruction. Part Two contains detailed suggestions for teaching each unit of the course. Part Three gives lists of apparatus and materials, suggestions for ordering and caring for apparatus, and also the addresses of laboratory supply companies. Part Four presents certain bibliographical and source materials.

2. OBJECTIVES OF SCIENCE STUDY

The ultimate and practical objective or goal of science study at any level of intellectual attainment is the desirable modification of the responses of the student in life situations. What science subject matter and what methods produce the greatest beneficial result in the life of the pupil is the question which teachers must constantly ask themselves. This concept of education demands that we analyze our science materials and our methods of instruction with the hope of discovering which knowledge, attitudes, habits, appreciations, interests, and ideals are most worth-while. Many analyses of this kind have been made.

At the present time there is no conclusive method of evaluating the objectives of science study. One method which is commonly employed is that of consensus. A few years ago an analysis was made of the objectives found in fifty-one general-science courses published since 1925.* In general, the objectives may be grouped in six classes: Knowledge, Exploration, Abilities, Attitudes, Ideals and Habits, and Interests. The frequency of mention of these various objectives is shown in Table 1, pages 4-5. This frequency of mention is interesting, but is not a valid criterion for determining what the objectives should be. It reveals what others consider to be the objectives.

Another approach to the problem of deciding upon the objectives to be attained has been through appointment of committees by various associations. A committee of the National Society for the Study of Education presented its report in the Thirty-first Yearbook of the Society entitled "A Program for Teaching Science." This report was published in 1932. The point of view of this committee is expressed in the following quotations from the report:

> An aim of education that seems consistent with the postulations of modern philosophy is, *Life Enrichment through Participation in*

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* Instruction in Science, Bulletin, 1932, No. 17. Monograph No. 22, United States Department of the Interior, Office of Education.

> *a Democratic Social Order.* . . . The point of view taken here is that life enrichment is in part, and in large part, developed from the understanding of principles and generalizations that ramify into human experience. These principles and generalizations are functional in that they furnish a background for intelligent response to stimuli that recur in common unspecialized experience. The understanding of principles and generalizations comes from the association of ideas that are developed from experiences. These understandings are products of the activities of the school if the ideas from which they are developed are products of classroom activities. It is clear, then, that the school will contribute to life enrichment if its activities are of the kind from which ideas may be developed and if the ideas may in turn be associated with principles and generalizations that are woven into human experience. . . .
>
> A functional understanding of a principle has been attained if the learner has acquired ability to associate with the principle the ideas from his immediate and from his subsequent experiences that are directly related to it and if he is able to apply the principles in practical situations. . . . The objectives may be stated as principles and generalizations that are functional for the individual, in that they enable him to interpret the experiences of living. The objectives may be formulated (1) as statements that function directly in thinking, (2) as statements that describe methods of thinking, and (3) as statements that describe attitudes toward products of thought and toward methods of thinking. These three types of objectives, though distinguishable, cannot be regarded as mutually exclusive. From the point of view of their origins in the educative process, these objectives are closely similar. The findings from science have contributed enormously to thinking, to methods of study, and to the development of scientific attitudes that affect behavior. The principles and generalizations of science must, therefore, occupy considerable place in a program of general education the aim of which is life enrichment. (Pages 42-43)

The *Report of the Committee on the Function of Science in General Education* of the Commission on the Secondary School Curriculum of the Progressive Education Association was published in 1938. This committee states the aim of secondary education in the paragraph at the top of page 6.

TABLE 1. AN ANALYSIS OF THE OBJECTIVES LISTED IN [illegible] COURSES OF STUDY IN GENERAL SCIENCE*

TYPES OF OBJECTIVES	[illegible]
A) Knowledge	
1. To acquire information about science	[illegible]
2. To acquire knowledge which will produce a better understanding of our environment	[illegible]
3. To acquire the knowledge necessary to correct superstitions and erroneous beliefs	[illegible]
4. To acquire a scientific vocabulary	[illegible]
5. To acquaint the student with the source of scientific knowledge	[illegible]
6. To acquire information concerning the lives of the great men of science	[illegible]
7. To acquire a body of facts which will enable one to read scientific literature	[illegible]
8. To acquire a knowledge of the fundamental principles of the subject	[illegible]
9. To acquire a knowledge of the application of principles in industry	[illegible]
10. To acquire the knowledge necessary for future work in science or to prepare for college	[illegible]
11. To acquire knowledge which will function to secure the objectives stated in the bulletin on Cardinal Principles of Secondary Education	
a) Health	[illegible]
b) Citizenship	[illegible]
c) Worthy home membership	[illegible]
d) Vocation	[illegible]
e) Worthy use of leisure time	[illegible]
f) Development of ethical character	[illegible]
B) Exploration (or Orientation)	
1. To give the pupil a view of the field of science so that he may explore his interests, capacities, and abilities	[illegible]
a) as a basis for the election of further courses in science	[illegible]
b) as a basis for the selection of a vocation	[illegible]
c) to acquire new fields of interest	[illegible]
C) Abilities	
1. To develop the ability to think scientifically	44
a) to develop reliance on facts	5
b) to develop the power of interpretation	10

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* From *Instruction in Science*, Bulletin, 1932, No. 17, Monograph No. 22, United States Department of the Interior, Office of Education.

TYPES OF OBJECTIVES	TIMES LISTED
c) to develop the power of observation	19
d) to develop the ability to form independent judgments	12
e) to develop the ability to evaluate	3
f) to develop the ability to generalize	1
g) to develop the ability to locate problems	1
h) to develop the ability to plan prior to execution	1
i) to develop the ability to gather data systematically	2
j) to develop the ability to recognize defects and errors in conditions and processes	1
2. To develop the ability to use the scientific instruments common in the laboratory	4
D) *Attitudes*	
1. To develop a scientific attitude as shown by ability—	
a) to view facts objectively	2
b) to be free from dogma and superstition	2
c) to hold one's conclusion as tentative and to suspend judgment until facts are secured	3
d) to revise one's opinions if the evidence warrants	1
e) to have a spirit of inquiry	11
f) to be open-minded	12
g) to have a conviction of the universality of the cause and effect relationship	3
2. To develop attitudes of appreciation of—	
a) the contributions of scientific method	7
b) the contributions of science to mankind	20
c) the great men of science	8
d) expert judgment	5
e) nature	12
f) one's responsibility in the world	5
g) natural laws	4
E) *Ideals and Habits*	
1. To acquire ideals and habits of accuracy, persistence, honesty, self-control, truth, etc.	16
F) *Interests*	
1. To acquire an appetite for investigations in science	8
2. To acquire an appetite for scientific reading	9
3. To acquire an interest in taking more science	10
4. To acquire an interest in nature	10
5. To acquire interests in vocational fields	2
6. To acquire wholesome interests which may be used to enjoy spare time	14

> The purpose of general education is to meet the needs of individuals in the basic aspects of living in such way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society. Needs arise and work themselves out in living, dynamic events which can only be described as interactions between the individual and the social situation. . . . Thus when we speak of the need of the student to select and use goods wisely, we refer to a want (biological tension) or a desire on the one hand, and the requirements, demands, standards of social living on the other.*

The point of view of the committee is interesting in view of the controversy between the advocates of the "child-centered" curriculum and the believers in the "society-centered" curriculum. Advocates of the "child-centered" curriculum have demanded that learning activities be based upon the immediate felt needs or desires of pupils. Those who believe in a "society-centered" curriculum maintain that the business of education is to fit the pupil to live in an organized society. They believe that we should seek our objectives by a determination of the qualities, skills, abilities, etc., demanded for successful participation in this society. The demands of society should thus constitute the basis of our curriculum rather than the needs of pupils.

It is evident that the committee of the Progressive Education Association does not subscribe to either of the viewpoints. It rejects the "child-centered" curriculum because such a curriculum leaves out of consideration the demands of social living. It rejects the "society-centered" curriculum because such a curriculum neglects the biological tensions or wants of the individual. The committee believes that most situations have two aspects, personal and social; that the needs of the adolescent arise from an interaction between the individual and the social situation; and that the teacher must be concerned with the total situation, which includes both the individual and his environment.

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* *Science in General Education* (New York: D. Appleton-Century Co., 1938).

As a basis for the analysis and classification of needs the committee set up four centers of reference in terms of basic activities of living. These activities and the needs of adolescents to carry on these activities of living effectively are as follows:

A) Personal Living
   1. The need for personal health
   2. The need for self-assurance
   3. The need for a satisfying world picture and a workable philosophy of life
   4. The need for a range of personal interests
   5. The need for esthetic satisfaction

B) Immediate Personal-Social Relationship
   1. The need for increasingly mature relationship in home and family life, and with adults outside the family
   2. The need for successful and increasingly mature relationship with age mates of both sexes

C) Social-Civic Relationship
   1. The need for responsible participation in socially significant activities
   2. The need for social recognition

D) Economic Relationship
   1. The need for emotional assurance of progress toward adult status
   2. The need for guidance in choosing an occupation and for vocational preparation
   3. The need for wise selection and use of goods and services
   4. The need for effective action in solving basic economic problems

The committee then considers the personal characteristics essential to democratic living. These are discussed in terms of the types of behavior that are desirable to foster. They include social sensitivity, tolerance, coöperativeness, the disposition and ability to use reflective thinking in the solution of problems, creativeness, self-direction, and esthetic appreciation.

To implement effective social participation and the realization of personal potentialities the individual must "understand the society in which he lives, the factors that are strategic in it, and the processes by which it operates and changes." The task of the curriculum-maker is therefore that of a search for the "understandings" that will bring about the desired changes in pupils. These understandings can be formulated in terms of the generalizations which when learned become incorporated in the individual as adaptations in personality resulting in intelligent behavior.

Each of these three reports has helped science teachers develop more clearly their views of the function of science in the education of boys and girls. It is in the light of these reports that the authors have selected the learning products, or objectives, aimed at in the *Science Problems* books. These objectives are as follows:

1. *An understanding of those generalizations of science that a citizen of a modern democracy needs in order to solve everyday personal, social, and civic problems.* Two criteria must be used in the selection of generalizations: (a) They must meet the needs of the pupils and the requirements of social living, and (b) they must be within the comprehension of most of the pupils who will take the course.

2. *An understanding and appreciation of the importance to oneself and to society of the applications of scientific generalizations and discoveries.*

3. *The development of a scientific attitude of mind.* One who possesses a truly scientific attitude has the following characteristics:

a) He has an inquiring turn of mind; he wants to know the what, the how, and the why of things.
b) He holds his conclusions subject to revision in the light of new evidence and revises those conclusions if the evidence warrants.

c) His judgments are as unprejudiced and as impersonal as possible.
d) He is careful and accurate in what he does.
e) He is free from dogma and superstition.
f) He is tolerant toward new ideas and suggestions.
g) He plans prior to execution.
h) He distinguishes between fact and opinion; he is slow to accept as facts, statements that are not supported by evidence.
i) He respects the judgments of experts.
j) He appreciates the value of science (both methods and subject matter) in living.

The development of a scientific attitude is a product of the method of instruction employed in the course. The teaching plan of the book, which employs the inductive method of approach to the major principles and generalizations and the problem method of organization, has as one of its major purposes the development of the scientific attitude.

4. *Growth in the ability to do critical thinking.* One learns to think by thinking. The activities, self-testing exercises, and problems to solve suggested in the course are of the type which demands reflective thinking. (An excellent analysis of reflective thinking and methods of encouraging reflective thinking is given in *Science in General Education.**)

5. *The development of wholesome intellectual interests and appreciations which lead to a desirable use of leisure time and which give a basis for educational and vocational guidance.*

The extent to which these changes take place in boys and girls through the study of science depends upon how skillfully the teacher directs the science activities toward their production. These objectives are not meaningless aims which should be read by the teacher and then forgotten. Each day's work should contribute to some extent to their realization. If this is to be the result, the teacher should know how each of the activities carried on by the pupils helps carry the pupil forward.

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* *Ibid.*, chap. vii.

3. PRINCIPLES AND PLAN OF ORGANIZATION OF THE SERIES

Before describing the method of organization employed in this series, let us consider the study materials which have been commonly used in general-science classes. Consultation with many teachers of junior high-school science and observation of the work done in classes reveal that much of the reading material is too difficult for a large number of the students we now have in our junior high schools. This difficulty appears to be the result of a complex of several factors.

CURRENT DIFFICULTIES WITH STUDY MATERIALS IN GENERAL SCIENCE

1. *One cause of the difficulty of much general-science material is the method of organization employed.* The majority of general-science texts are organized almost entirely around environmental units or topics. When an environmental unit is presented, the generalizations of science needed to make the relationships within the unit clear are introduced when needed. In the earlier units of the course this makes necessary the introduction of an excessively large number of principles per unit, with the result that both the principles themselves and the environmental topics suffer.

To make clear the above statement, let us take a conventional unit on Weather. To develop a reasonable understanding of this unit, the following concepts and principles must be developed: temperature, radiant energy, reflection, absorption, evaporation, relative humidity, condensation, air pressure, convection currents, and the relationships of air pressure, temperature, and humidity in bringing about changes in weather. Now if we add the concepts dealing with thermometry, various forms of precipitation, areas of high pressure, areas of low pressure, isobars, isotherms, lightning, thunder, tornadoes, and weather prediction, we can easily see why such a unit is difficult. Environmental topics or units are naturally quite complex and involve a large number of relationships to interpret. Before such units are attempted, it would seem that some method must be employed to insure that a large number of the generalizations needed shall have been already developed.

Under the type of organization just discussed little if any provision is made for really teaching the principle to the point of functional understanding, that is, to the point at which the pupil can use the principle to interpret problems of a widely varying content. As a principle is introduced, application can be made only to the aspect of the environment being considered. If the principle is applied to the interpretation of any and all phases of the environment in which it supplies an explanation, the unit is thrown out of focus. For example, the idea of atmospheric pressure is introduced in the unit "Weather." It is needed to explain winds and their change in direction and in the prediction of the weather by the barometer. Now the idea of air pressure also explains how buildings are heated, pumps, vacuum-cleaners, non-skid tires, breathing, and innumerable other phenomena, devices, and processes. If we stopped, however, at this time, to use this idea to explain all of these things, weather would be entirely forgotten. The unit would be out of focus.

It is at this point that we get an explanation for the criticism of teachers that pupils do not learn the principles to the point where they will function. Really to learn a principle the pupil must practice using the principle as a method of explanation in all sorts of environmental situations. Through practice he acquires skill in analyzing situations to discover the problematic elements which determine the mode of attack and also skill in recognizing the situations in which the principle of science is the basis of explanation.

The introduction of a principle in an environmental unit results in ability to use the principle to interpret a specific situation relating to the unit at hand. Unfortunately, it does not transfer to other situations because it has not been generalized; that is, the pupil has not used the principle in a wide enough variety of situations to realize it and to accept it as a general mode of interpretation. He does not connect the air pressure which causes wind with the air pressure which operates a vacuum cleaner or sends heated air upward from a hot-air furnace. They represent different things to him because they have not been associated in his experience.

The result of using principles only in the specific situations in which they are developed is a source of difficulty in later units. For example, a unit on water supply may follow the unit on weather. We need the idea of air pressure to explain the operation of pumps. We assume that pupils already have the idea because it has been presented in the weather unit. They do have the idea in connection with the specific situation encountered in that unit, but they have not really learned the principle, that is, developed it to the point of a general mode of interpretation. The teacher and the text assume that the idea is already understood; they therefore spend no time on it, and the result is that the new material becomes difficult because it assumes an understanding which is not present.

One cannot really blame the author of the text or the teacher for this. If time is spent developing the implications of a principle each time a situation is encountered, a two-thousand page textbook would be needed, and many additional hours would be required for teaching. The difficulty is inherent in the method of organization. To make our text material easier we must correct this difficulty that arises from the method of organization.

2. *Another source of difficulty is the encyclopedic treatment of concepts.* This difficulty arises in part from the fact that general-science courses cover an exceedingly large field. In order to present the vast number of concepts included in general-science courses, explanations have been condensed into as few words as possible. Psychologically this is unsound.

To make an idea easy it must be developed step by step, and this must be followed by a development of its implications. The logical outcome of such condensed encyclopedic treatment is mere verbalism. The pupil associates a principle with a series of words which have no meaning to him. It is no wonder that the principle does not become a part of his mode of behavior, that is, a method of explaining the world in which he lives. This is another difficulty that we must correct if we are to make the subject matter easier.

3. *A third source of difficulty relates to the style of writing.* This is in part the outcome of the encyclopedic method of presenting the concepts.

Other sources of difficulty are also found, but those discussed —organization of the units, encyclopedic nature of the treatment, and style of writing—are the most important.

ORGANIZATION OF THE SCIENCE PROBLEMS SERIES

Our first step in trying to eliminate these difficulties was to analyze the environmental units to discover what principles and generalizations (understandings) of science were needed to secure intelligent behavior on the part of the pupil with respect to the aspects of environment treated in the series. This analysis provided a list of all the principles needed, and, more important than this, showed the extent to which each principle was needed as a method of explanation. The analysis showed, first, the frequency of use, and, second, the importance of the principle.

For example, an understanding of the nature of chemical change was needed in the following units of the series: How do we use and control fire? How are plants and animals alike? How do plants and animals get food? Why do we eat different kinds of food? How does the earth's surface change? How do we use energy? How do our bodies work? How can you help your body fight disease? How does man take care of the plants and animals he uses? How do we make electrical currents? How do we use electrical current? How do we harness the energy of nature to do our work? and How can science help us keep from wasting nature's wealth? Apparently in chemical change we find a fundamental concept that needs to be developed to the point of general functional understanding. Furthermore, it is apparent that the concept needs to be introduced early in the course. Further analysis showed just what aspects of chemical change need be considered.

In a similar fashion it was discovered that concepts and principles relating to the nature of matter, the effect of heat upon matter, the cell structure of living things, the force of gravity, and the nature and use of energy were also basic to a large number of environmental units. It is apparent, also, that these concepts have an interpretive value in their own right quite apart from their relationships with other concepts in complex environmental units.

The authors therefore decided to take these fundamental concepts and principles and organize them into real teaching units. In these units the concepts and principles are carefully developed, and the pupil is shown how to use them to interpret a wide variety of situations. Through the use of exercises and problems he is given an opportunity to practice using the generalizations to explain problematic situations. In this way it becomes possible to teach the principle to the point of functional understanding, which, as we mentioned earlier, is extremely difficult if the course is organized solely on the basis of environmental units.

The reader may see the contrast between the two methods of development if he will read Unit 5 of Science Problems, *Book 1*, "How can one kind of substance change into another kind?" Thirty-four pages are used for this presentation. In the conventional general-science text the understandings relating to chemical changes will be found scattered through the entire book. In no one place will be found an adequate treatment of the generalizations needed to understand this vital aspect of daily living. Similar units are developed for the other major concepts and principles listed in the first paragraph on this page. These units are placed in the course to precede the environmental units for which they supply an explanation.

With a text organized in this fashion it becomes possible to develop environmental units as they should be developed. When we consider an environmental unit, the task is to show

how the various phenomena, processes, and materials which constitute the environment are interrelated to provide the conditions and effects which the environment affords. Consequently, if we are to place our emphasis upon the interrelationship, the basic principles and concepts must be regarded as prerequisite to the unit. For example, the majority of books in general science present from thirty to forty pages on weather. At least three-fourths of this space is utilized to develop the principles and concepts mentioned on page 10. A correctly focused treatment would presuppose an understanding of the principles and would focus on an understanding of how the changes in relationship between air pressure, temperature, and humidity result in changes in weather. It is true, of course, that some science principles and concepts must be developed in each environmental unit because only those of broadest application have been singled out for special attention in units focused directly upon them. But the number of principles so needed is reduced, making the environmental unit less difficult and making it possible to focus more directly upon the understandings of the unit.

One criticism which may be urged against the method of organization is that it is a return to the old "specialized-science" type of treatment. This, however, is not the case. The specialized-science treatment is essentially deductive in character. It presents a principle and then applies it. Let us contrast this with the method employed in this book.

In general the problems in these units start with one or more environmental situations. These situations are those common in the life of the pupil and pose the question, "How can we explain this?" Then the principle is developed through experimentation. The original situation is explained, several more environmental situations are presented, and the pupil is shown how to use the idea to explain these situations. In the Self-Testing Exercises and the Problems to Solve he is given other situations to explain by means of the principle. These afford the opportunity to practice using the principle. It is really during this practice that he generalizes and makes the idea his own.

Thus the teaching plan is inductive-deductive in character. It starts with an environmental situation that presents a challenge to the pupil and ends in the use of the generalization to explain new environmental situations.

Another criticism which may be made is that the presentation of science principles and generalizations in "science" units rather than in "environmental" units is opposed to the idea that science should be "socialized." This raises the question, What is meant by "socializing" science? For example, how do we socialize Archimedes' Principle? Archimedes' Principle is socialized when it can be used by the pupil to carry on more effectively the activities of everyday living, or, more specifically, when it can be used in those situations in our environment which depend upon the use of Archimedes' Principle for explanation, for prediction of possible effects or inference of conditions past or present, or for deciding upon some course of action. This means, first, that the pupil be taught to recognize the kinds of situations that may be explained by reference to the relationships presented in the principle; second, that he be able to use this set of relationships to explain causes and effects involving this set of relationships; third, that he be given practice in using Archimedes' Principle to explain those aspects of his environment which are made clear by the principle.

The crucial step in socializing a science principle is in providing for the use of the principle in carrying on the activities of everyday living. The treatment of science principles in this series is such that it does provide opportunity for the pupil to use the principle for explaining, predicting, and doing.

PLAN OF SCIENCE PROBLEMS, BOOK 1

To the majority of pupils who will study this book, science is a new subject—just another subject that they will have to study. They have little or no idea of the nature of the subject matter of science and no idea of how the body of tested knowledge that we call science has come into existence. For these reasons it was decided to open the series with two orientation units in *Book 1*.

The first unit, "How do scientists make discoveries?" serves the purpose of introducing the pupil to the nature of the work done by the scientists. It is particularly important at the beginning of the course that the pupil get an idea of the methods of work employed by the scientist. We must get across the idea that the findings of science are accurate and may be relied upon. To do this, we must give the pupil an idea of the careful, accurate work demanded of the scientist. The young learner must see how the sensitive instruments of the scientist make it possible to secure results which could not be obtained by one's unaided senses. Science is regarded by many people as "magic." We must show the pupil that science is not magic. The discoveries and inventions are marvelous, but they are based on tested knowledge made possible by the methods and instruments employed. Furthermore, we should, insofar as we can, "sell" the pupil the method of thinking that the scientist uses. Of course, this unit does not teach the pupil to think better. It does, however, make the pupils aware of the fact that there is a better method of thinking which can be trusted to result in a more valid conclusion than the "hit-and-miss" methods of everyday thinking.

The purpose of the second unit, "What kind of world do you live in?" is to give the pupil a bird's-eye view of the world in which he lives so that he may see the kinds of problems that each aspect of the world presents. We live in a world where certain *conditions* are present. We are surrounded by certain *materials* and *living things*. We have certain kinds of *forces* that enable us to deal with our environment. And finally, we have a certain *kind of body* which determines how we can live in this world. Science is a method of explaining this world.

Unit 3, "What is a material?" presents some of the basic concepts related to the structure of matter: what matter is, the states of matter, solutions, and the molecular theory. This unit provides the basis for understanding the changes that matter can undergo, as discussed in the next two units.

Unit 4, "How do heating and cooling change materials?" is another unit that presents some basic concepts. The effects of heating and cooling upon the size and state of materials are fundamental concepts in most environmental situations.

Unit 5, "How can one kind of substance change into another kind?" is an elementary treatment of chemical change. The necessity for this concept in a large number of units has already been discussed.

With the three units just completed, it is possible to present environmental Unit 6, "How do we use and control fire?" At this point the value of the three preceding "pure-science" units can be seen. No adequate treatment of fire would be possible without the concepts presented in Units 3, 4, and 5. One hundred four pages were required for these three units. Manifestly it would be impossible to expand the unit on fire 58 pages to include these ideas. The only alternative would be to present a condensed, encyclopedic treatment of each of these concepts. If this were done, the concepts would not be taught to the point of functional understanding; therefore they could not be applied intelligently in this unit. The result would be mere verbalism and not true understanding.

Unit 7, "How do magnets work?" was included at this point because it is easy and of interest to boys and girls. The concepts are needed in units later in the series.

Unit 8, "How are plants and animals alike?" presents the basic concepts necessary to understand the problems of all living things. It unifies some of the concepts presented earlier and goes one step further in presenting the idea of all structure.

Unit 9, "How do plants and animals get food?" carries on the story from the previous unit in explaining one of the major life activities. It applies again the idea of solution and chemical change.

Unit 10, "Why do we eat different kinds of food?" supplies the basis for understanding one of man's fundamental problems. The practical nature of the unit and the need of pupils for guidance in the selection of proper food formed the basis for the inclusion of the unit at this point in the series.

Unit 11, "How do plants and animals live together?" is an environmental unit which naturally follows Units 8, 9, and 10 in that it shows the interrelationships among living things—interrelationships which result from the dependence of living things upon each other for a food supply. This unit of subject-matter was also included here because of its seasonal character. Normally this unit will be studied in the late spring. At this time of year field trips can be arranged, and first-hand observations may be made.

PLAN OF SCIENCE PROBLEMS, BOOKS 2 AND 3

Book 1 naturally does not represent a complete coverage of the units to be considered in a course in general science. In order that teachers may see the relation of *Book 1* to the other books of the series, an outline of *Books* 2 and 3 is included. A study of this outline will show why certain concepts which could have been incorporated into the units of *Book 1* are omitted and are placed in later units of the series.

UNIT-PROBLEM OUTLINE OF *Book 2*

UNIT 1: What Is the Relation of the Earth to Other Heavenly Bodies?
- *Problem 1:* What is the earth?
- *Problem 2:* What is the solar system?
- *Problem 3:* What is the nature of the universe?
- *Problem 4:* How do the earth's movements affect us?
- *Problem 5:* How do astronomers learn about the heavenly bodies?

UNIT 2: How Is the Force of Gravity Useful to Us?
- *Problem 1:* What effects does gravity have?
- *Problem 2:* How do we use gravity to measure materials?
- *Problem 3:* How does gravity affect liquids?
- *Problem 4:* How do we use the pressure of the atmosphere?
- *Problem 5:* How does the force of gravitation differ at different places?

UNIT 3: How Does the Earth's Surface Change?
Problem 1: How are rocks changed into soil?
Problem 2: How are materials carried from place to place?
Problem 3: How do volcanoes change the earth?
Problem 4: How are mountains formed?

UNIT 4: Why Do Some Things Rise and Others Sink in Fluids?
Problem 1: Why do some objects float and others sink?
Problem 2: How does gravity cause water and air to circulate?

UNIT 5: How Do We Use Energy?
Problem 1: What is energy?
Problem 2: What do we do with energy?
Problem 3: What are the different forms of energy?
Problem 4: How do we change one form of energy into another?

UNIT 6: How Do We Control Heat?
Problem 1: How does heat travel from one place to another?
Problem 2: What happens to heat when a material changes from one state to another?
Problem 3: How do we keep our buildings warm?
Problem 4: How do we keep things cool in warm weather?

UNIT 7: What Makes the Weather Change?
Problem 1: What causes the different kinds of weather?
Problem 2: Why does the weather change from day to day?
Problem 3: How are weather forecasts made?

UNIT 8: How Do Our Bodies Work?
Problem 1: How is the body put together?
Problem 2: How do our cells keep alive?
Problem 3: How does the blood move through the body?
Problem 4: How does our food dissolve and get into the blood?
Problem 5: How does your blood get oxygen and get rid of carbon dioxide?
Problem 6: How does the body get rid of its nitrogen wastes?

UNIT 9: How Can You Help Your Body Fight Disease?
Problem 1: What are disease germs?
Problem 2: How do germs make us sick?
Problem 3: How do our bodies fight disease?
Problem 4: How can we help our bodies fight disease?
Problem 5: How can we help prevent the spread of disease germs?

UNIT 10: How Does Life Continue on the Earth?
- *Problem 1:* What are some of the ways in which living things reproduce?
- *Problem 2:* How do seeds grow into plants?
- *Problem 3:* How do animals grow?

UNIT 11: How Does Man Take Care of the Plants and Animals He Uses?
- *Problem 1:* How do farmers improve their soil?
- *Problem 2:* How does man protect his plants and animals from their natural enemies?
- *Problem 3:* How does man select food for his animals?
- *Problem 4:* How does man provide proper housing for his animals and plants?

UNIT-PROBLEM OUTLINE OF *Book 3*

UNIT 1: How Do Living Things Behave?
- *Problem 1:* How do human beings behave?
- *Problem 2:* How do animals behave?
- *Problem 3:* How do plants behave?

UNIT 2: How Do Scientists Classify Living Things?
- *Problem 1:* What do scientists do when they classify living things?
- *Problem 2:* What are the kinds of animals that have no backbones?
- *Problem 3:* What are the characteristics of animals with backbones?
- *Problem 4:* What plan of classification does the scientist use?
- *Problem 5:* What are the different kinds of plants?

UNIT 3: How Are Plants and Animals Fitted to the Conditions Around Them?
- *Problem 1:* How are animals and plants fitted to live in water?
- *Problem 2:* How are animals and plants fitted to live on land?
- *Problem 3:* How do the structures of living things protect them from their enemies?
- *Problem 4:* How does man fit his environment?

UNIT 4: How Do Simple Machines Help Us Do Work?
Problem 1: What are machines used for?
Problem 2: Why do machines help us do work?
Problem 3: What are the kinds of simple machines?
Problem 4: How do we control friction in our machines?

UNIT 5: How Do We Make Electrical Currents?
Problem 1: How do electrical charges behave?
Problem 2: How do we control electrical current?
Problem 3: How do we use chemical change to make electrical current?
Problem 4: How do we use mechanical energy to make electrical current?

UNIT 6: How Do We Use Sound?
Problem 1: What is a sound?
Problem 2: Why do sounds differ from one another?
Problem 3: How do musical instruments produce sound?
Problem 4: How do we hear?
Problem 5: How are sound waves reproduced?
Problem 6: How do we control sound?

UNIT 7: How Do We Use Light Energy?
Problem 1: How does light behave?
Problem 2: How do we use reflected light?
Problem 3: How do we use light in our homes?
Problem 4: How do we use lenses?
Problem 5: Why are objects of different colors?

UNIT 8: How Do We Use Electrical Current?
Problem 1: How do we get heat and light from electrical current?
Problem 2: How is electricity measured?
Problem 3: How do electrical currents do work?
Problem 4: How is electrical current used to cause chemical changes?
Problem 5: How is electrical energy transmitted to our homes?
Problem 6: How is an electrical current used for sending messages?

UNIT 9: How Do We Harness the Energy of Nature to Do Our Work?

Problem 1: How is the energy of wind and water put to work?
Problem 2: How do we measure power?
Problem 3: How do we use steam to harness the energy of fuels?
Problem 4: How is the energy of fuels harnessed by internal-combustion engines?
Problem 5: How is harnessed energy transmitted?
Problem 6: What sources of energy will men use in the future?

UNIT 10: How Does Man Improve Plants and Animals?

Problem 1: Why are offspring like their parents in some ways and different from them in other ways?
Problem 2: How are desirable kinds of plants produced?
Problem 3: How are desirable kinds of animals produced?

UNIT 11: How Have Living Things Developed on the Earth?

Problem 1: How do geologists discover the history of the earth?
Problem 2: What have geologists learned about the living things of the past?
Problem 3: Why do we find different kinds of living things in different places?

UNIT 12: How Can Science Help Us Keep from Wasting Nature's Wealth?

Problem 1: How can we save our soil?
Problem 2: How can we save fuel for future use?
Problem 3: How can we best enjoy our wild animals?
Problem 4: How can we make the best use of our forests?

INTERNAL ORGANIZATION OF THE UNITS

INTRODUCTORY EXERCISES. At the beginning of each unit is a series of Introductory Exercises. These exercises have four purposes: (1) They serve as a basis for recall of previous knowledge or experiences which may be of value in the study of the unit. (2) They enable the teacher to pick out the students who are poorly equipped to enter upon the study of the unit because of inadequate preparation or lack of experience with nature. (3) They enable the teacher to select the parts of the unit which

may be of general difficulty to the whole class. (4) They stimulate interest in the new unit.

LOOKING AHEAD. This part of each unit is developed in a variety of ways but always has three important purposes: (1) to help the pupil see what the unit problem really is, (2) to make the pupil feel and understand the importance of the unit to him, and (3) to arouse an active interest in the study of the unit.

PROBLEMS AND SUB-PROBLEMS. Each unit is divided into major problems focused on the larger concepts to be developed in the unit. Each problem is further divided into sub-problems focused on minor concepts essential to an understanding of the major problem. It should be noted that the problems and sub-problems are focused on understandings which have interpretive value. The subject matter presented in the problems and sub-problems is the assimilative material or the data used by the pupil to arrive at an understanding.

SELF-TESTING EXERCISES. The Self-Testing Exercises are of two types: those testing the pupil's comprehension of the generalizations developed and those testing his ability to use the generalizations to interpret or explain problematic situations. They provide practice in using the idea.

PROBLEMS TO SOLVE. The Problems to Solve are designed to give the pupil practice in using the ideas to interpret more complex situations than those included in the Self-Testing Exercises. As such, they require a greater depth of thinking and provide opportunities for the brighter pupils. They also call for additional reading, observation, collecting, and experimenting.

LOOKING BACK. The type of summary exercise varies from unit to unit, but each has the same general purpose: that of requiring the pupil to look back over the unit, select the important ideas, and state them in concise and organized form.

ADDITIONAL EXERCISES. These exercises provide supplementary activities and problems which require further investigation for solution. They suggest projects and experiments of various kinds which may be carried out. On pages 411-414 of the text is a list of readings which may be used in this connection and also to suggest additional types of work.

4. SUGGESTIONS FOR FITTING THE COURSE TO LOCAL CONDITIONS

The authors have selected and arranged their material with great care. Where classes meet every day and the periods are not too short, each book presents an excellent year's work. When the classes meet only two or three times a week or the background and abilities of the pupils are below average, study of an entire book will probably require too superficial a treatment. In such cases it will be better to modify the course by omissions and varied treatment of units than to hurry through all of them. The teachers in each school or school system should study their own situation and choose with care the material to be taught.

Because of the interdependence of units, selections and omissions require careful examination of the sequences that have been built into the books. To assist teachers in scheduling the units and in making necessary selections of content Table 2 has been prepared. The time schedule presented in the fourth column of the table is arranged to fill 34 weeks. This is about the amount of time that will be available for teaching in a school with a nine-month term. The schedule will, of course, vary when units or parts of units are omitted. The actual amount of reading of content material and of directions for experiments is indicated in the fifth column. This quantity, together with the number of experiments to be done, is used to determine, in general, how much time will be needed for the unit in relation to the other units to be taught.

The last two columns of the table are intended to be helpful when the course must be modified for any reason. The last column indicates variations that can be made. In connection with this column it should be kept in mind that the more able pupils can often be led to study or at least read parts of a book that are not included as required work for all pupils. The second column from the right indicates what material in the book should have been studied before each unit is taken up.

Suggestions for omitting certain units should not be taken as

TABLE 2. SUGGESTED TIME SCHEDULE FOR TEACHING SCIENCE PROBLEMS, BOOK I

* UNITS	*PAGES OF READING	NUMBER OF EXPERIMENTS	TIME ALLOTMENT IN WEEKS†	COVERAGE PER WEEK		BACKGROUND MATERIAL IN PRECEDING UNITS	POSSIBLE MODIFICATIONS IN TREATMENT
				Pp.	Exp.		
1. How Scientists Work	17	0	1½	12	0		May be used as reading unit with little discussion or written work.
2. What Our World Is Like	23	0	2	12	0		May be used as reading unit.
3. Materials	18	5	3	6	2—		May omit optional problem (Prob. 4), at least for slow students.
4. Effects of Heat	20	5	3	7	2	Unit 3: Probs. 1, 2 Unit 3: Prob. 4 desirable	May omit optional problem or, in case of necessity, the entire unit.
5. Chemical Change	21	7	4	5	2	Unit 3: Probs. 1, 2 Unit 3: Prob. 4 desirable	May omit optional problem (Prob. 4).
6. Fire	28	9	5	6—	2	Unit 3: Probs. 1, 2 Unit 4: Probs. 1, 2, 3 Unit 5: Probs. 1, 2, 3 Unit 5: Prob. 4 desirable	

7. Magnets	20	10	3	7−	3+	None for required problems Units 1, 2, 3 desirable Unit 3: Prob. 4 for optional Prob. 4	May be omitted without breaking a sequence. May omit optional problem (Prob. 4).
8. Nature of Living Things	18	4	2½	7	2−	Unit 5: Probs. 1, 2 Unit 6: Prob. 1	May be read carefully with little written work.
9. Getting Food	26	9	4	6+	2	Units 3, 5	May omit optional problem (Prob. 4).
10. Diet	23	1	3	8−	—	Unit 3: Prob. 3 Unit 5 Unit 8: Probs. 2, 3 Unit 9	
11. Interdependence of Living Things	22	1	3	7−	—	Units 3, 5, 9	Important but may be omitted.
Total	236*	51	34	Average			
				7	1½		

*Exclusive of pictures, legends, and exercises. · Including experiments and tables.
†Assumes school year of 34 weeks.

indicating lack of importance of the material. Necessity may require that the time spent on the course be reduced. In such circumstances it is better to omit some content or to use it for supplementary reading than to "cover the ground" at a rate which reduces interest, destroys the scientific attitude, and makes training in scientific thinking virtually impossible.

5. TECHNIQUE OF INSTRUCTION

The plan of organization of this book makes it possible to use any of the commonly accepted methods of teaching. It is a "unit-plan" book and as such is focused on the attainment of functional understandings. The assimilative materials necessary to develop these understandings are contained in the book. The teacher may employ any method he thinks desirable to use this assimilative material.

In the past fifteen years there has been a tremendous spread in the use of what is called the unit method of teaching. In this method of instruction the teaching is divided into five phases: (1) exploration, (2) preview, (3) assimilation, (4) organization, and (5) recitation. While this plan of teaching is not a necessary concomitant of the method of organization of this book, a brief statement of the technique is included here because of the many requests of teachers.

EXPLORATION

The purpose of this phase of the work has been discussed in the paragraph on "Introductory Exercises," page 23. Experience has indicated that it is a good plan to have the pupils write out the answers to the Introductory Exercises so that an individual diagnosis is possible. It is not expected that the students will be able to answer all questions correctly. Some of the exercises are based on the study material in the text. A few pupils may have progressed much farther than the average, and if their answers to the Introductory Exercises show that they thoroughly understand certain parts of the unit, they may be allowed to work on the Additional Exercises or projects.

Some teachers discuss the answers to the Introductory Exercises after they have been written. If this practice is followed, care should be taken not to discuss those exercises that are based on the new study material. The exercises which are answered in the unit and which should not be discussed will be evident from an examination of the text. After the papers have been examined by the teacher, they may be returned to the pupil at the end of the work on the unit with the incorrect exercises marked. The pupils may be instructed to correct their answers when they have completed their study of the unit. Such practice will reveal to the pupil the progress he has made and his change of viewpoint during his work on the unit.

Preview

The purpose of the preview has been discussed under the section, "Looking Ahead," page 24. The preview may be presented in the form of a 15- or 20-minute talk by the teacher; that is, the teacher may read the "Looking Ahead" section as given, outline it, bring in additional illustrations of his own, and then present it in the form of an informal lecture. The introductory comments for each unit will also serve to suggest the content of the teacher's talk as an introduction to the unit. There is a wealth of historical material which may well be brought into the preview of the unit. Progress in the development of man's control of some phase of the environment supplies an excellent background upon which to project his present state of control and serves to indicate further advances which may be made. It is suggested that the teacher supplement each preview with additions of this kind. Space limitations made it impossible to present as much of the historical material in the previews as the authors think would be advisable.

If this method is followed, the pupils listen to the talk, and at the end of it are required to write out their own idea of the unit as obtained from the talk. This gives valuable training in listening and in written expression.

Another plan is to have the pupils read the "Looking Ahead"

section and then outline it. This will insure that they see the unit in its entirety and that they see the relationship of the problems and the contribution of each to the unit. Some teachers may wish to use a diagram of the unit similar to the unit graphs in this manual. Whatever method is followed, care should be taken not to include details in the preview. In his study of the unit the pupil will undertake to round out the general ideas brought out in the preview and answer the questions inspired by it.

It has been observed in some classrooms that teachers follow the presentation with a true-false test on the facts presented This procedure does not usually follow out the idea of the presentation. It tends to become a test of what the pupil remembers of the factual statements made in the presentation. Such a method is simply a test of what the pupil remembers of what the teacher said. The primary function of the presentation is orientation. The most significant test is, "What are the problems which you will try to solve in this unit?" The answers to this question will show the teacher whether or not the pupils have caught the general idea of the unit. The answers will show whether or not the general plan of the unit is grasped; in other words, whether or not the pupils are correctly orientated.

Three general types of learning activities are employed.

a) *Listening to the spoken word.* This activity involves the ability to follow through a talk without losing the train of thought. To do this, one must be able: (1) to pick out important points, (2) to recognize that illustrations and examples are used to clarify the speaker's thought and are minor details, (3) to concentrate on what the speaker says, (4) to make a mental summary of the main points as the speaker talks, and (5) to learn to identify different methods of organization used. After the talk the pupil must be able to recapitulate the main points. This he will ordinarily do by making an outline of the main points, keeping them in sequence, and then filling in the details.

b) *Taking notes on talks.* In taking notes the same activities are involved as in listening. In addition, however, the pupil

TABLE 3. Scheme of Instruction Technique

STEPS IN THE LEARNING PROCESS	STEPS IN THE CLASSROOM TECHNIQUE	STUDENT ACTIVITY INVOLVED	TESTING RESULTS
Stimulus or Motivation or Seeing the problem	Exploration (1)* or Pre-test Review previous work Recall experiences pertinent to unit	Discussion and written work	Questions and exercises
	Preview (1) Teacher's sketch of unit—15 to 20 minute talk with simple demonstrations	Listening, observing, note-taking, or Reading preview in text	Written or oral composition on preview
Study (directed) or Reflection or Solving the problem	Individual or group study (5–20)	Reading Extensive Intensive Experimentation Field trips Drawing Observation of motion pictures Observation of demonstrations Demonstration before class Responses to exercises	Oral quizzes Written quizzes Composition True-false tests Completion tests Best answer Summaries Reports on experiments Discussion before class Interpretation of new situations Self-testing exercises Problems to solve
Reaction or Application or Use of knowledge	Organization (1–2)	Preparation of outline, summary, or syllabus of unit	(The activity is itself the test.)
	Recitation (1–2)	Oral and written recitation	(The activity is the test.)

* The numbers in parentheses following steps in classroom technique suggest the approximate number of periods to be given to each step.

must learn to write words or short phrases which will help him recall the main points of the talk. The most common error in taking notes is that the pupil will try to write everything the speaker says. This is of course impossible, and the pupil soon loses the train of thought. A good method of teaching note-taking to young students is to present part of the preview involving one main idea; then stop and show the pupils what notes they should have taken. This may be repeated until they catch the idea and are able to take notes on a talk lasting for twenty or thirty minutes.

c) *Observing motion pictures.* Sometimes the best way to get an overview of the unit is by use of a motion picture. When used for this purpose, the film should be run and followed by a discussion in which the questions or problems raised by the film are listed. These should not be answered at this time but should serve as a basis for introducing the problems of the units.

ASSIMILATION

In this phase of the work the learning activities of the pupil himself are the major concern. Through his own activity he is to gain an understanding of the problems of the unit. To guide the pupil in his study during the period of assimilation, the authors have broken up the main problems into sub-problems. These sub-problems focus the attention of the pupil on the important sub-ideas necessary to solve the problem. The great help given by the sub-problems can only be appreciated by comparing this type of organization with the conventional topical heading. The material included under each sub-problem is definitely focused on the solution of the major problem. In the majority of texts it will be found to be impossible to word the topics in the form of sub-problems and then find the material included to provide a solution for the problem.

The study material proceeds step by step, raising questions, introducing facts and principles through reading and experimentation when an actual need for them is felt. In other words, the method of teaching is inductive and is incorporated into the

study material. It is essential that each pupil solve the problem for himself, since it is through his own activity that understanding is finally reached. Fundamentally, a textbook should be regarded as a source of data for solving problems. It presents the assimilative materials which may be used to arrive at certain understandings; therefore, memory of the assimilative materials is not the end product of a course. These materials are merely a means to the end. When teaching a given unit, the teacher has in mind certain understandings, abilities, attitudes, and interests upon which the assimilative material should focus. The question is, therefore, "What activities shall I have my pupils carry on with these assimilative materials to accomplish my objectives?" The assignment (the activities set up by the teacher) is therefore the crucial factor in determining the learning products that will result.

There are many types of learning activities. Certain types are best adapted for certain kinds of learning. The teacher's task is to select that type of activity most likely to be successful in bringing about the desired result. In science a large part of the learning is essentially a process of acquiring meanings. When a thing, a situation, or an event has acquired meaning, it is understood. Perhaps the best statement of this idea has been given by Dewey: "To grasp the meaning of a thing, an event, or a situation is to see it in its relation to other things, to note how it operates or functions, what consequences follow from it, what causes it, and to what uses it can be put."

If we follow Dewey's idea, we can see that we need a variety of learning activities focused on each understanding, so that the idea may be approached from many angles. The book provides some of these angles of attack. Discussion in class can be most advantageously carried out if you formulate learning activities which attack the idea from a different angle. The more difficult the idea, the greater the number of types of learning activities that must be employed. Using a different set of learning activities for discussion from those given in the assignment also results in more thinking and greater interest.

To assist the teacher in formulating different types of learning activities, the following list is provided. When you make an assignment or prepare activities for classroom discussion, glance through this list and find appropriate types of activities. An example of each type of activity is included.

One of the objectives of an introductory science course is that of acquiring certain skills and abilities. To realize this objective, activities must be provided involving these skills and abilities, the attention of the pupil must be fixed upon correct methods of procedure, and sufficient practice must be given for the pupil to attain them. The following discussion therefore will consider some of the types of activities provided for in the *Science Problems* series and also give some suggestions for teaching pupils how to carry on these activities.

1. STUDY READING. *Reading for study is of an analytical* nature. The following method is suggested for this book:

a) *Read with a definite purpose in mind.* This requires a thorough comprehension of the problem to be solved. The pupil's question to himself should be "What am I trying to find out?" To test his comprehension of the problems, the student should frame it in his own words. Most pupils look upon study as learning what the text says. That is not the attitude desired in science.

b) *Read through the entire problem to get a general idea of the whole, always keeping in mind the question which you are trying to answer.* Stopping to clear up obscure points or to look up new words wastes time, because in a great many cases these will be cleared up by further reading of the problem. This first rapid reading will also furnish the pupil a basis for judging the relative importance of the different parts of the subject matter, which will assist him in distributing his time. He should look especially for sign-post or summary paragraphs and topic sentences. Pupils have become so used to studying carefully everything they read that it is sometimes difficult to get them to do this type of reading. Pupils of this age ought to read about 250 words per minute, which is about the number of words per

page. To get them to understand how you want them to read, set a time limit; that is, if the problem is five pages, give them five minutes to read it. This time varies with different classes, and the teacher can by experiment determine the best rate for each class.

c) *Reread the problem more carefully.* In this step the pupil should make a careful analysis of the subject matter. The following directions will assist pupils in this analysis:

1) Keep the problem constantly in mind and examine the subject matter in light of this problem.

2) Note carefully italicized words. These words are new words and are defined in the text. Be sure that you understand their meaning before you go on.

3) Try to picture in your "mind's eye" or make a sketch of the materials or articles described.

4) Try to relate the material to something which you already know.

5) Try to determine why the writer went from the first point to the second, and so on.

6) Use the illustrations. Each illustration or diagram was put in the text for the purpose of helping you understand more easily. Ask yourself "What does this picture show?"

7) Make in your own words a topical sentence for each paragraph. Remember that each paragraph has some one idea necessary to the understanding of the whole and that all of these ideas will furnish an outline of the problem.

2. OBSERVING MOTION PICTURES. Motion pictures provide another way of getting experiences. They should be just as carefully selected to fit into the unit or topic being studied as a demonstration or reference would be. Motion pictures are of special value as means of assimilation when it is desirable (1) to extend experiences with industrial processes or natural phenomena that are inaccessible because of time and space limitations, (2) to show phenomena and processes that are not easily observable, (3) to explain and clarify by animated diagrams, and (4) to vitalize the work.

There are certain principles of using films which have demonstrated their values:

a) The "build up" or preparation should be just as carefully carried out as for a key demonstration unless the film itself carries such a "build up."

b) The teacher should try to develop an atmosphere that will lead to the seeing of the picture as an interesting and enjoyable learning experience rather than a piece of pure entertainment or as a basis for a quiz on all of the details, which may kill the pleasure and satisfaction of seeing the film.

c) Whenever practicable, the film should be shown in the regular classroom to maintain a normal atmosphere rather than a "show" atmosphere.

d) At the first opportunity after showing the film, pupils should be given a chance to ask questions. The teacher may often start quizzing and let pupils carry on as soon as they begin asking questions.

e) After the picture has been run, use its content. Ask questions that can be illustrated or explained by what was seen in the picture.

f) After a discussion both of the picture and of the related material in the unit, it is often advisable to raise questions which are answered in the film but which were not made clear at the first showing. The film should then be re-run for this purpose.

3. Listening to explanations. It is often advisable to supplement the study material with explanations by the teacher. Occasionally the explanation is best given before the pupils study, but as a rule the explanation should be supplementary rather than introductory. In such explanations teachers should make abundant use of the blackboard for diagrams and outlines.

If the explanation involves processes which split into different parts or phases, it is good practice to stop at the end of each phase and ask for questions upon parts that are not clear. Pupils should be made to feel that it is their responsibility to ask for further information if the explanation is not clear. If the ex-

planation is followed by a written question involving the use of the idea presented, pupils are more likely to take the responsibility seriously because they know that an explanation is followed by a quiz.

4. OBSERVING EXPERIMENTS. In observing an experiment the pupil should ask himself "What is the purpose of this experiment? What results are obtained? What conclusions can be drawn?" Younger students quite frequently look upon the manipulation of the apparatus as the end of the experiment and fail to realize that the experiment has been performed for the purpose of providing data for the answer to some question. To obtain this questioning attitude, the teacher should allow each member of the class to formulate his own conclusions. If the teacher states the conclusion, the members of the class will get into the attitude of focusing their attention on the manipulation of the apparatus, knowing that when the experiment is over, the teacher will explain it.

5. PERFORMING EXPERIMENTS IN THE LABORATORY OR FOR DEMONSTRATION. Since the method of the book is inductive in character, the experiments are introduced when data are necessary for the solution of the problem. Laboratory work is therefore not an end in itself; it is, rather, a step in problem solving. Where separate class periods are designated for laboratory work, the teacher should precede this work by a class discussion of the problems for which the experimental data are to be obtained.

If the laboratory work is to be of value, it must be carefully supervised. The pupil should:

a) know the purpose of the experiment;

b) make a careful analysis of the apparatus to be used (if necessary, an analytical drawing should be made);

c) watch everything that happens and see how it is related to the purpose of the experiment;

d) see how one step is related to another—the relation of cause to effect.

e) formulate conclusions on the basis of observed results;

f) apply his conclusions to the problem in hand.

The following directions to pupils have been found helpful in teaching them how to experiment:

a) Before you do an experiment, you should have clearly in mind the purpose of the experiment, that is, the problem you are to solve. This is necessary so that you may understand why the experiment is done in a certain way. It also helps you to get clearly in mind the nature of the facts that you are trying to discover. Ask yourself questions such as these: What is the purpose of this experiment? What am I trying to discover?

b) Next, you should read the entire experiment through to find out (*1*) how the experiment is to be performed, (*2*) the purpose of each part of the experiment, and (*3*) the kind of observations you are to make. Many students make the mistake of reading an experiment line by line, doing what the directions say. When they get through, they do not know what they have done because they have not kept clearly in mind exactly what they were trying to find out.

The best method is to read the experiment all the way through and then ask yourself: What is the first thing I am to do? What will I find out if I do this? What is the second thing I must do? etc. Another question to ask is, "Why is this method used in the experiment?" If you are going to learn to experiment for yourself, you must find out why scientists experiment the way they do.

c) Now you are ready to do the experiment. Follow directions exactly. Sometimes, of course, you may have to use slightly different apparatus from that called for, but the procedure should be followed with great care. The first lesson that you should learn about experimentation in science is *accuracy*.

d) Next, consider what you have learned from the experiment. In other words, what are the results that you obtained? "What did I discover from doing this experiment?" is a good question to ask.

e) Now you are ready to draw your conclusions on the basis of the facts you have collected. Your conclusions should answer the purpose in your mind when you began your experiment.

6. TAKING FIELD TRIPS. One of the most important types of learning activities in science is that of obtaining direct, first-hand contact with the materials, forces, things, processes, and phenomena of our daily environment. To a very great degree learning in science must be based upon perceptual experiencing. We may bring materials into the classroom for the pupils to observe, or we may perform experiments, but in each of these cases we are taking the thing or process, etc., out of its environmental setting. Really to understand a thing or a process we must see it in its natural setting; we must see it in its relationships to other forces, things, materials, and processes. For this reason field trips should be taken whenever and wherever possible.

There are certain principles of accepted practice that may be useful to the beginning teacher in planning field trips:

a) No field trip should be conducted without a definite purpose in the mind of both teacher and pupils. The teacher must decide ahead of time exactly what data are to be obtained on the trip.

b) The teacher must visit the places to be observed before the trip is taken so that he knows exactly what is to be seen, the location of the specific points of observation, and the order in which the observations are to be made.

c) The pupils should understand what a field trip is for and have the proper attitude toward it. They should see that things can be learned on field trips which cannot be learned from books, that on field trips they see things as they really are, and that they must know what to look for as they make their observations. They must understand that they are to keep together, that they must not talk while the teacher is talking, and that they should ask questions if they do not see what the teacher is talking about.

7. SOLVING THE SELF-TESTING EXERCISES AND THE PROBLEMS TO SOLVE. It has been found that the attention of the pupils can be most effectively focused upon the important concepts presented in the book through one or more Self-Testing Exer-

cises on each problem. Thus the Self-Testing Exercises are a very important part of the study of the problems in each unit. They serve the following important purposes:

a) Test the pupil's understanding of the problem up to that point.

b) Inform the pupil whether or not he is ready to proceed and can understand that which follows.

c) As an integral part of the study material, often refer to illustrations and to the text and thereby furnish links between what precedes and what follows.

d) Give the teacher objective evidence of the progress of each pupil.

e) Emphasize the important concepts necessary to an understanding of the unit.

f) Furnish a definite basis for self-activity.

g) Give the pupil training in measuring his own accomplishment.

h) Provide for a large number of intellectual activities of the types used in the scientific method of study.

Because of the importance of the proper use of these exercises in the correct methods of study, the teacher should see that they serve as many of the purposes listed above as possible under the teaching situation in his classes. The Self-Testing Exercises should be done by all pupils in the class. They can all be solved by proper use of the data contained in the text.

In addition to the Self-Testing Exercises, Problems to Solve have been provided. They include a wide range of activities which in general require a greater depth of thinking than the Self-Testing Exercises. As a rule, the emphasis is upon the use of the idea in explaining some environmental situation, in predicting results which follow certain conditions on the basis of science principles, or upon using the ideas to carry on some practical activity. They also include activities that are focused upon an extension of the ideas presented in the text.

The Self-Testing Exercises and Problems to Solve include the following different types of learning activities:

1. Examining a series of specific cases to arrive at a concept of class. (*What are the characteristics of a chemical change?*)

2. Examining a series of specific cases to arrive at a concept of relationship. (*How does the work put into a machine compare in amount to the output of the same machine?*)

3. Selecting facts on a given basis. (*Name three substances that are very elastic.*)

4. Judging the adequacy, relevancy, correctness of conditions, factors, statements, etc. (*In what respects does your local water supply meet the requirements of a good water supply? Criticize the following statement: Frost is frozen dew.*)

5. Comparing two processes, events, etc., to arrive at a concept of likeness and differences. (*In what ways is the human body like and unlike a machine? Compare a steam engine with a gasoline engine.*)

6. Arriving at a judgment of the relative values of two or more devices, theories, etc. (*Which kind of fuel is best for the average small home? Which theory of the origin of the solar system best explains the facts?*)

7. Experimenting. (a) To determine effect produced. (*Determine by use of an iron ball and ring the effect of heat upon a metal.*)

b) *To evaluate.* (*Which is the best conductor of heat—copper, or iron?*)

c) *To discover relationships.* (*How does the amount you can lift with a lever change when the force-arm is lengthened?*)

d) To verify principles. (*Perform an experiment to verify Archimedes' Principle.*)

e) Formulating plans for original experiments. (*Plan an experiment to find which of two vacuum bottles is the better.*)

8. Observing. (*Observe the direction and length of your shadow at different times of the day.*)

9. Discussing and summarizing, involving the selection and organizing of material. (*Discuss Law of Conservation of Energy.*)

10. Outlining. (*Make an outline of the reading material on how the balance of life is brought about.*)

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11. Explaining. (*Explain why the ticket-taker on a merry-go-round leans in toward the center. Why does a region of low pressure bring rain?*)

12. Making models or devices. (*Make a waterproof sand table in which your class can see erosion occuring.*)

13. Verifying. (*Cite evidence to show that typhoid fever is caused by a germ.*)

14. Dramatizing. (*Write the directions for three people who are to demonstrate how the sun, moon, and earth move.*)

15. Reconstruction through imagination. (*Write a diary of a trip from Washington to New York in 1775.*)

16. Stating examples for the purpose of illustration. (*State an experience of your own to illustrate a chemical change.*)

17. Classifying. (*What kind of a simple machine is used in the following devices: windlass, oar, etc.?*)

18. Illustrating facts graphically. (a) Graphs. (*Make a graph to show the relationship between the season of the year and the amount of water needed.*)

b) Maps. (*Make a map to show the paths of "highs" and "lows."*)

c) Diagrams. (*Make a diagram of the ventilating system of the school.*)

d) Plans. (*Draw a plan to show how crops are rotated on a farm that has four fields of equal size.*)

e) Cartoons. (Draw a cartoon to show the pull of gravity.)

19. Analyzing and using graphic material. (a) Graphs. (*Given a temperature graph, when was the temperature the highest?*)

b) Maps. (*What does the map show regarding the amount of rainfall in Kansas?*)

c) Diagrams. (*Describe the apparatus shown in the figure.*)

d) Tables. (What *conclusions can you draw from the facts given in this table?*)

e) Photographs. (*How does the picture show that either the earth or the stars move?*)

20. Obtaining data from original sources. (*Find out from a manufacturer how artificial ice is made.*)

21. Taking field trips. (*Study your own neighborhood to find out what measures are taken to keep it clean.*)

Increased skill in determining types of learning activities and their uses can be obtained by classifying the Self-Testing Exercises and Problems to Solve under the types given.

8. METHODS OF USING THE EXERCISES IN SMALL AND LARGE CLASSES. The method of using the exercises will vary in accordance with the teacher's decision to use the group or the individual method of instruction or a combination of these two plans. Whatever plan is used, there arises the question of available time to mark the papers. A few suggestions for handling this important phase of the technique are therefore in order. Since the amount of time available for this purpose is largely a matter of the size of classes, the suggestions are given in two groups, one for small classes and one for large classes.

a) *Small Classes.* Before they attempt the exercises, pupils should be instructed to read through the problem for a bird's-eye view of it, and then to make a second slower reading for details. If the problem contains experiments, the pupil should perform these as he reaches them. Since pupils progress at different rates of speed, only a few sets of apparatus will be found necessary. When the exercises on a given problem are completed, the paper is handed to the teacher and is graded immediately. Thus it is not necessary for many papers to be graded after school, and, furthermore, the teacher may confer with the pupil about the paper at the psychological moment. In cases where any point is causing confusion to the class as a whole, the teacher may find it advisable to clarify the point by a brief exposition or explanation.

If the exercises are not completed satisfactorily, the papers are immediately returned to the pupil. With beginning pupils it is worth-while to indicate in the margin the type of error. In general, the faulty answers may be classified as incomplete, incorrect, too broad, or off the question. Abbreviations of these words can be used in the margin to indicate each error. The pupil then corrects his paper and returns it to the teacher as many times as is necessary for him to do the exercises correctly.

If a record is kept of the number of attempts and the types of errors made by each pupil, it can be used as a basis of conference with the pupil. Every teacher knows that exhortations on methods of study and general directions for study have little value. Pupils will change their methods of study only when they have concrete evidence that their own method will not produce results, and when the teacher can demonstrate that another method is better. The records furnish this concrete evidence and lay the foundations for selling a better method to the pupil. For this reason the procedure followed is: first, give the pupil something to do; second, show him his error, if any, and try to indicate the fault in procedure which caused the error; and third, have him repeat the exercise or give him other exercises of a similar nature.

An excellent record form for pupil progress is illustrated on page 45. This record form is mimeographed and a copy is given to each pupil. The record indicates the final date of acceptance of the activity, the number of trials or attempts required to complete the activity in a satisfactory manner, and the types of errors made. The instructor initials the last column when the activity is accepted. At the end of the unit the instructor collects these records and enters the results in a master chart as shown in Table 4 and Table 5. The time of the teacher may be saved by passing the master chart to the pupils and having them enter their results on the chart.

A typical time record of completed exercises for one of the units is shown in Table 4, page 46. Several types of pupils are shown. The table is read as follows: Pupil A completed Exercise 1 correctly on the second day, Exercise 2 on the third day, Exercise 3 on the fifth day, and so on. Pupil A also worked on the Additional Exercises on the 14th, 15th, 16th, and 17th days. Pupils A and R are consistent, average workers. Very little attention from the teacher is necessary. Pupil B either loafed at the beginning of the unit or had considerable difficulty with Exercise 1. On the evidence of the record, K looks like a loafer or a very slow learner. The fact that he worked well toward the

RECORD OF PUPIL PROGRESS ON UNIT Hour........

Science Course.................... Name....................

Unit No......... Title......................................

Instructions. This sheet is to be a complete record of your work in the unit. List the written assignments of the unit in their order and attach your papers to this sheet each time you submit them, giving the date in the proper column the first time you submit a paper.

The mark on the paper at each attempt and the date of approval will be indicated by the instructor. Key to marks for errors: C—Content, M—Mathematics, F—General Form, ?—Doubtful meaning, X—English or other usage errors, I—Incomplete.

	Type of Assignment	Date	Mark on Paper					Instructor's Mark
			1	2	3	4	5	
1	*Pre-test*	9/2						9/2JCM
2	*Presentation Test*	9/3	X	OK				9/4JCM
3	*Self-Testing Exercise 1*	9/8	OK					9/8JCM
4	*Self-Testing Exercise 2*	9/10	I	I	OK			9/14JCM
5	*Etc.*							
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

TABLE 4. TIME RECORD OF COMPLETED EXERCISES

Pupils	1st day	2d day	3d day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day
A		1	2		3		4	5	6		7	8	9–10	AE*	AE	AE	AE
B							1	2	3		4	5	6–7	8	9		10
F	1	2		3		4	5	6	7	8	9	10	AE	AE	AE	AE	AE
K		1		2			3			4	5	6	7	8	9	10	
Mc	1	2	3	4	5	6	7	8–9	10								
R		1	2	3	4	5	6	Absent	Absent	7		8		9	10		

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* AE, Additional Exercises.

last part of the unit when everyone else was finishing would indicate that he can work under pressure. Pupil F is a rapid, consistent worker, doing more than the average of the class (the required number of exercises was 10; Pupil F did five Additional Exercises). Pupil Mc is an extremely rapid worker. She completed the required exercises very quickly and spent the remainder of the time on a supplementary project. An examination of the number of attempts required will help interpret the results of Table 4.

The record of the number of attempts required is shown in Table 5. Each time a pupil hands in an exercise, he is credited with one attempt on it. Under the system followed it is necessary that he complete it correctly. The number of attempts therefore measures his efficiency of work. The table reads as follows: Pupil A completed Exercise 1 correctly on the first attempt. Pupil B required four attempts on Exercise 1. It will be noted that Pupil B really did have trouble on Exercise 1. The large number of attempts required classifies him as a slow learner rather than as a loafer. Pupil K is now readily identified as a loafer. His small number of attempts shows that he could not have been working during all of the time he required to

TABLE 5. NUMBER OF ATTEMPTS REQUIRED

Pupils	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Total
A	1	1	1	1	1	2	1	1	2	1	12
B	4	1	2	3	2	1	2	1	2	1	19
F	2	1	1	2	1	1	1	1	1	2	13
K	1	2	1	1	1	1	2	1	1	1	12
Mc	2	1	1	4	2	1	2	1	1	2	17
R	2	1	1	1	2	1	2	6	2	1	19

finish the unit. This conclusion, however, should be followed by observation of the pupil, because it is possible that he might be an extremely slow, conscientious worker. If he is identified as a loafer, he may be shown these charts and be asked to account for his slowness. The teacher can then show him that it is due primarily to his dilatory habits. Pupils A and F need very little attention. Pupil Mc is working too fast. She would do better to slow down and thereby decrease the number of attempts necessary. She is sacrificing accuracy for speed. Pupil R and Pupil B need more careful diagnosis and attention, as suggested by the large number of attempts necessary.

Pupils may be kept informed of how their rate of progress compares with that of others by keeping a chart record of the progress of different members of the class and posting the chart in the classroom. However, there lies in such practice the danger of encouraging hurried and careless work.

b) *Large Classes.* Where classes are so large and where the study and teaching facilities are such that individual supervision of the pupils at work is impracticable, the teacher should plan to use the exercises in such a way that they serve as well as possible the purpose for which they are intended without overburdening himself with papers to be corrected. The doing of all of the Self-Testing Exercises, or of equally valuable exercises prepared by the teacher, is quite essential to the proper study of the text. Without such activities the work is likely to fall back to the unprogressive assignment-recitation form of instruction. In accordance with the purposes of the exercises, the following flexible plans for using the exercises in large classes and under conditions unfavorable to the best teaching are suggested for the teacher's assistance in making the study of the pupil effective:

1) Have pupils write reports on all exercises. Require certain ones to be handed in for your inspection. The pupil should not know beforehand which exercises will be called for, thus insuring that he does his best on every one. Nor is it necessary to have every pupil submit the same exercises. By such plan the teacher will have a check on the work of each pupil and not

overburden himself with papers to be corrected. Exercises not called for may be taken up in class discussion, pupils being asked to read their reports for criticism by the class.

2) Pupils may be asked to hand in certain exercises and to make brief notes on the points which they would include in reports on those not collected. The latter may then be considered in class discussion.

3) Pupils may be asked to write an answer to each of the sub-problems raised and to the major problems. The teacher can then first read the answer to the major problem. If this is correct, it is not necessary to read the answers to the sub-problems. If the answer is incorrect, the error will usually be found among the answers to the sub-problems. In case such an error is found, the teacher may direct the pupil to solve the sub-problem again and then to solve the major problem again.

4) Where the technique is entirely of the group instruction plan, pupils may be asked to make notes for their reports on each exercise in the text or to write their reports and be ready to report in class discussion of the problem. This is probably the least desirable of the plans suggested, for it does not, per se, insure individual thinking and activity, and does not lend itself so well to directed or supervised work.

5) If the group method of instruction is carried on, it is essential that it be adapted to the spirit of the book, which is inductive. First, a problem is raised; this is in turn broken up into smaller problems, each of which is solved by the presentation of certain data or by experiment, and the results of all are combined into an answer to the problem. As a rule this final combination organization must be done by the pupil in answer to the exercises.

A good method of group instruction is therefore to raise the problem with the pupils and get it firmly in mind by requiring several restatements of it by the pupils. Then have the class read through to the first experiment. This experiment may then be performed by the teacher in demonstration, or it may be performed by the pupils working in groups, or by the individual pupils, or by some one pupil. It is important in this connection

to let the pupils draw their own conclusions. Then turn back to the reading of the problem until another experiment is reached, and go through the same process.

When all of the experiments have been performed and the class has finished reading through the problem for the first time, set them doing the exercises. This in most cases will require further study of the problem. In order to be sure that each pupil does his own work, it is essential that these exercises be done in class if possible. Some of the brighter or faster pupils will probably finish before the rest of the class, and these may be supplied with additional exercises or supplementary projects until the group is ready to go on. Before beginning the next problem, it may be advisable to have a class discussion of the previous problem to insure that all have obtained an understanding. Any pupil who has done his exercises incorrectly can then correct them.

A plan such as outlined breaks the period into several parts: study, experimentation, and discussion.

ORGANIZATION

When the students have given satisfactory evidence (in assimilation tests) that they thoroughly understand a unit, that they really know the essential facts and relationships, they should proceed to the next step in the learning process—organization. Without books, notes, or other helps, each pupil is required to represent in some way the relative importance of the ideas in the unit and their interrelationships. The organization may take the form of (*a*) a list of the main ideas in statement form, (*b*) a statement or topical outline of the unit, (*c*) a diagram of the unit (see the graph for each unit).

There is a marked tendency for the pupil to include a large amount of assimilative material in the organization. This is particularly true if the outline is made too detailed. At first, it is probably best to have pupils make only the main points. As they attain skill in this process, they may be allowed to make their outline in more detail.

The organization, if properly used, provides a strong stimulus for thought about the facts and relations of the unit. It is not

to be regarded as a test, but as a step in the learning process. However, in so far as it is a thinking exercise and not an outline of the memorized text discussion, it is a quite reliable index of the pupil's ability to organize facts in a conscious and independent way. More than any other assignment of a unit, it stimulates growth in thinking power. (For detailed suggestions see the "Looking Back" sections and the unit graphs in this manual.) Motion pictures are often very helpful in showing pupils the unit in perspective and assisting them in picking out essential elements.

RECITATION

Following the completion of the organization by all the pupils, one or two periods may be given to oral or written recitation. The selection of recitation topics and the procedure in the recitation may follow several different plans, depending somewhat on the type of unit. In many cases the topics should be such that they will call for a re-presentation of the entire unit under a new organization. In other units a presentation of some part of the unit is advisable. Under any plan used, the student is expected to present his talk in a clear, well-organized, straightforward fashion, and in good English. He should assume that he is speaking to an audience made up of those who have not studied the unit. Any member of the class or the instructor may call upon the student to elucidate any point in his talk. Following the oral recitations those pupils who have not given satisfactory recitations and those who have not had an opportunity to speak may be required to write on a topic selected by the instructor.

In order to add interest to the recitation, the instructor may suggest to the pupils that they incorporate in their talk any additional material obtained from their reading or from talking the topic over with their parents. Pupils interested in some one phase of the unit may have done additional work on this phase. They can also be given opportunity to present the results of their investigation. [illegible] suggest topics not directly based on [illegible] but re-

(N.C.E.R.T.)

quiring that both speakers and listeners use their new understandings.

It is commonly the practice where the group plan of instruction is used to have a series of recitations on small blocks of the subject matter from day to day. It is highly advisable, however, to carry on the recitation for the whole unit as outlined above. This will furnish a review and will also insure that the unit is seen in its entirety rather than as a series of apparently unrelated facts and principles.

Correlation with Other Subjects

The written work in science affords the opportunity for correlation with the English department. The preview and the written recitation, both in narrative form, give excellent training in English composition. After the paper has been corrected for science, it may be turned over to the English teacher for further correction or elaboration. The organization, which is usually written in outline form as a series of statements, will also give the English teacher concrete material upon which to work. This may also be sent to the English teacher for correction. Quite often the English department will arrange to give credit for the written work in science. Drawings of apparatus, machines, etc., can often be arranged for in connection with the manual arts department. Concepts developed in Units 1, 6, 9, and 11 have important social implications and give opportunity for making direct connection with topics usually included in social studies courses.

Testing Results

Several methods of testing results have already been referred to, namely, the exercises, organization, and written recitation. If the individual plan of instruction is followed and the pupils are required to work on the exercises until they are correct, the number of attempts required is a good measure of efficiency. The number of days required to complete the exercises correctly is a good measure of their rate of work. For use in grading it is possible to give a passing grade for the correct completion of a given number of exercises and to base higher grades on the completion of a given number of additional ex-

ercises or supplementary projects. This will set up a definite standard of accomplishment for the class. The organization furnishes evidence on the extent to which the pupil has visualized the whole unit and upon his ability to grasp the interrelationships of the problems which make up the unit.

In addition to the above measures many teachers find it advisable to give a test on the entire unit. Such objective types as the true-false, the completion, and the best-answer can be used to good advantage in this connection. These tests have the advantage of being easily scored.

6. PRINCIPAL TYPES OF DIFFICULTIES ENCOUNTERED BY PUPILS

Real teaching does not stop with marking the exercises as correct or incorrect; it goes further and tries to diagnose the cause for the difficulty and to give corrective treatment. A list of difficulties, with diagnosis and corrective procedure, follows.

1. Misunderstanding the text or exercise. This is due in some cases to carelessness in reading the text or exercise and in others to attempting the exercise before having a complete understanding of the text. The most common types of errors are incomplete answers, incorrect answers, and off-the-question answers. These can frequently be corrected by having the pupil write the title of the exercise in his own words and show it to the instructor before he begins. Pupils who habitually misunderstand the exercises should be shown the value of the habit of restating the exercise in their own words.

2. Failure to identify the type of work needed to secure the answer. When confronted with a thought question, many pupils simply read the question over and then hunt through the text to find the answer. If they cannot find some direct connection between the thought of the question and some passage in the text, they give up and inform the teacher that the answer isn't there; others find a few phrases in the text which are similar to those used in the test and write them as an answer; others write everything they can find that has any bearing on the question. This results mainly in answers which are off the ques-

tion or too broad, with a sprinkling of incorrect and incomplete answers. Here again the pupils must be shown that their faulty answers are due to incorrect methods of procedure.

Corrective work, of course, varies with the type of test. In some cases the pupil has failed to strip the question of its setting, and thus cannot identify it with the correct principle or application. Corrective work consists in having the pupil (1) restate the exercise in his own words, (2) ask himself, "What do I have to know to answer this exercise?" and (3) ask himself, "How shall I go about getting the answer?" When a pupil has difficulties in determining his method of procedure, the teacher should show him the method to be used in that case, and then give him practice in problems of a similar nature.

3. FAILURE TO SEE RELATIONSHIPS BETWEEN EXPERIMENTS AND SUBJECT MATTER. *Science Problems* is inductive in character and proceeds from applications to principles. For example, the pump is first studied as a working device, and then experiments follow which present the principle of science involved in its operation. Many pupils become so interested in the manipulation of the apparatus that they lose sight of the purpose of the experiment. The experiment thus tends to become something apart from the problem. Since the text is inductive, each experiment contributes some one fact or principle necessary for complete understanding. Consequently a pupil who has not grasped the relationship between the experiment and the subject matter either gives up or frames some totally inadequate answer.

Since not all of the problems are experimental, it is very easy to identify such a pupil. In correcting this error the teacher must prove to the pupil that his faulty answer was due to a failure to see the contribution of the experiment. If on the next problem which includes experiments he is required to write out the principles or facts presented by the experiments and then to do the test, the ease with which he can do the test gives him concrete evidence of the value of the method. Some teachers will prefer to have pupils write a report on each experiment.

4. TENDENCY TO MEMORIZE THE TEXT RATHER THAN TO RATIONALIZE IT. Pupils who memorize rather than rationalize

can be identified by observation. They read the text over and over, frequently turning their eyes away from the book and gazing off into space. Many of them move their lips as they say over and over the words of the text. The results of memorizing the text are also apparent in the test results, which frequently contain a word-for-word reproduction. This practice is soon broken up if the tests are so constructed that they call for reflective thinking with the memory element in the background.

5. TENDENCY TO FORM CONCLUSIONS WITHOUT WEIGHING THE EVIDENCE. The tendency to form hasty conclusions appears quite frequently and results in incorrect answers. Such pupils generally have a large number of attempts on exercises. If the record of attempts is kept by days, these pupils can be readily identified by the large number of attempts on any given day. This type of pupil is usually very fertile in suggestions, but he does not evaluate these suggestions sufficiently before formulating his response.

The habit which must be broken is that of taking the first suggestion which comes to mind. The habit to be inculcated is that of recalling or formulating as many solutions as possible, and then testing each solution in the light of its applicability to the problem at hand. The tendency also results in incomplete answers. In a question which involves putting together several ideas contained in different paragraphs, some pupils obtain a partial answer in one paragraph and then fail to combine with it equally important ideas in other paragraphs. This may be caused by the fact that the pupil has not studied the problem as a whole and has failed to grasp the organization.

6. INABILITY TO DISTINGUISH BETWEEN MAJOR AND MINOR POINTS. The inability to select essentials crops out most frequently in making outlines and summaries. In many cases it is caused by lack of knowledge concerning chapter and paragraph structure, in others to a lack of definite purpose on the part of the pupil in his selection of facts. Here the pupil should be taught the significance of the problem and sub-problem titles in guiding him in the selection of his facts and the use of signpost and summary paragraphs and topic sentences.

7. FAILURE TO USE OR INTERPRET DIAGRAMS, TABLES, ILLUSTRATIONS, AND CROSS-SECTION DRAWINGS. Many pupils regard illustrations as something to be looked at and then passed over. As a result of this habit many pupils do not know how to study illustrations or read diagrams, tables, graphs, and section drawings. This is particularly true of section drawings. In order to assist pupils in the interpretation of such drawings it is sometimes necessary to have both an illustration and a section drawing of the same device. Practice can also be given in making section drawings from the actual apparatus.

8. INABILITY TO TRANSLATE THE PRINTED WORD INTO A THOUGHT-PICTURE. An example of inability to translate words into thought-pictures is found in describing the operation of a pump. Many pupils memorize the steps in the operation without actually seeing the significance of each step. One way to identify such pupils is to have them draw the pump in different stages of its operation. For example, suppose that the section drawing in the text shows the piston and the position of the valves at the beginning of the first upstroke, and the rest of the operation is explained in the text. If the pupil is asked to show the position of the valves and the piston on the first downstroke and the second upstroke, giving reasons for the different positions of the valves and the rise of the water through the cylinder, he will be forced to rationalize the process. Many pupils can tell glibly how the pump operates without having the slightest understanding of its operation.

9. SUMMARY. The results obtained in following the procedure outlined are evidenced in three ways: the reduction of the number of attempts required to do the test exercises, the reduction in the number of errors, and the reduction in time required to complete the units.

The supervision of study in beginning courses of science consists in setting up definite tests, the results of which are used not only to determine the extent of the pupil's understanding but also to find out the incorrect methods of procedure which are responsible for faulty answers. The results also furnish the basis for teaching pupils how to study.

PART TWO

Specific Suggestions for Class Work on the Units

INTRODUCTION TO THE COURSE

It is suggested that at the first class meeting teachers require the class to read the section in the text entitled "To the Boys and Girls Who Use This Book," pages v-viii. This reading will serve the following purposes:

a) Show pupils how the units and problems are organized.

b) Explain to pupils the purposes of the Introductory Exercises, Looking Ahead to the Unit, Self-Testing Exercises, list of Science Words, Problems to Solve, Looking Back at the Unit (Summary Exercises), Additional Exercises, and Readings in Science.

c) Give pupils some suggestions on how to use the various learning devices included in the text.

It is urged that the teacher spend some time discussing the organization of the book and the use of the different learning devices. The discussion may be made concrete by using Unit 1 to show the method of organization and the different learning activities. Teachers should previously read Section 5, Part I, pages 28 to 53, of this *Guidebook* to be thoroughly familiar with the function of the learning activities and with the organization of the units.

The use of the first class period for the purposes outlined above has been found to be a very satisfactory procedure. It not only gives the pupils something to do at the first class meeting, but it introduces them to the course and to the method that is to be employed in their own study.

UNIT 1

How Do Scientists Make Discoveries?

FUNCTION AND SCOPE OF UNIT 1. The purpose of this unit is to give the pupils a bird's-eye view of the ways in which a scientist works. At the beginning of a course it is highly desirable for pupils to see how the generalizations of the scientist are derived. One of the aims thus attained is an appreciation of the value of the findings of the scientist and a disposition to accept these findings as nearest to the probable truth. Furthermore, the pupil should see that the method of thinking employed by the scientist is a method which applies equally well to the thinking of the ordinary individual in solving the problems of everyday life.

Teachers should notice that this unit and Unit 2, which are orientation units, are not intended to be taught in great detail. They are meant to be read and discussed and illustrated until the general meanings are comprehended. Then their full significance will become clear to pupils as they study succeeding units. Teachers will do well to refer to Unit 1 whenever straight thinking is required on a problem of the class, and Unit 2 whenever the class takes up a new phase of the natural world.

Since these two introductory units do not lend themselves well to concrete experiments, such as are used to illustrate and aid in teaching the science principles of later units, teachers may need to vary their method of teaching during the time devoted to these units.

The graph of Unit 1 on page 59 will assist the teacher in seeing the unit as a whole and in selecting the points to be emphasized in the study of the unit. Accurate, detailed facts are necessary in all science work, but they only serve their purpose when they lead pupils to a clear understanding of the main ideas. When, through use of the facts the pupils have gained understanding and appreciation, the objectives of the teaching have been attained. Careful study of the unit graph by the teacher will pay high dividends in clarifying the objectives of the unit.

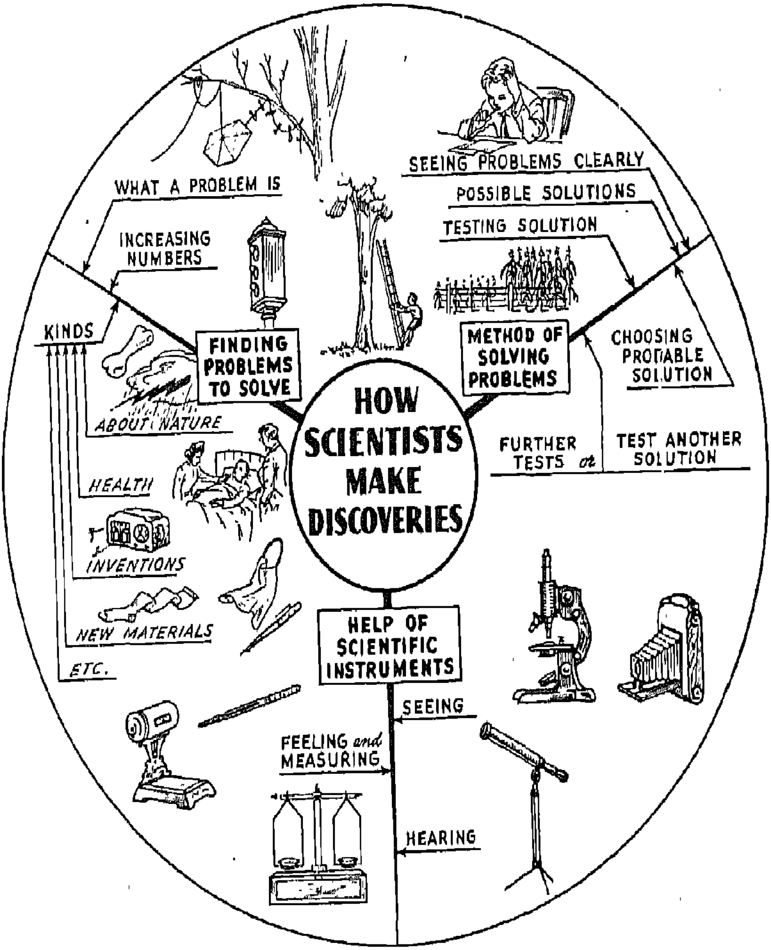

FIG. 1. GRAPH OF THE SUBJECT MATTER OF UNIT 1

pupils to list freely all sorts of problems—why a car won't run, causes of strange sounds, crop failures, differences between fields of corn side by side, health problems, weather problems, animal behavior, personal behavior, etc. Some illustrations are given in Problem to Solve No. 1 on page 15. But the perfunctory doing of this Problem to Solve and the Self-Testing Exercises will not always indicate the attainment of the purpose of the problem. Try to get your pupils to the point where they are sensitive to the problems that face them and their parents every day.

The pupils may be led to classify in various ways the problems they have listed. One way would be to mark them as falling in the field of science or in some other field. Skillful guidance will lead in many classes to a wealth of pupil problems which will later be solved in the study of science. They will not stop when the unit is concluded, but will keep coming week after week. In this connection many teachers may find a weekly "question period" useful. Science classes often appreciate fifteen to twenty minutes or more each week when they may ask their science teacher or science class any science question they wish, especially if it is not connected with the unit being studied at that time. Often one question will lead to another until a whole field of new interest is opened up. The nature of the question should determine the response. Other pupils may answer it. A few questions, but not too many, may be delegated to certain pupils to look up. The teacher may answer questions which are rather difficult for pupil research. Sometimes the teacher may just admit that he does not know or that scientists do not know the answer.

SELF-TESTING EXERCISES (P. 14). 1. A question or difficulty that arises in a puzzling situation.

2. Answers vary. The following are possible problems to be solved in everyday life:

a) You have a number of things that must be done and only a certain amount of time in which to do them. How can you get everything done? Planning your time is solving this kind of problem.

b) The same thing applies to planning the use of money—how to make your allowance spread over everything you need.

c) Your club is going to have a meeting. You have to plan where to have it, how to let people know about it, what to do at the meeting, etc.

3. Answers will vary. Some or all of the following should be mentioned: A scientist needs to be curious; he needs to be able to think up ways to test his ideas; he needs to be able to put the results of his tests together to make a complete explanation; he needs to be patient so that he is not discouraged if many of his ideas prove incorrect or his tests fail.

4. Some of these problems may be suggested: (*a*) Found explanations for various natural phenomena—change of seasons, determining time, etc.

b) Solved practical problems to find better ways of doing things.

c) Solved health problems.

d) Learned how to make new materials; found new ways of using old materials.

e) Learned how to harness the forces of nature in machines, etc.

5. Probably not, because (*a*) new problems are always arising as one discovery leads to another and (*b*) new situations are constantly arising due to changing conditions of life on the earth.

6. Aristotle decided what was true by thinking about what he saw and discussing it with other people. Galileo did experiments to test his ideas.

PROBLEMS TO SOLVE (P. 15.) 1. Answers will vary. The following are examples: (*a*) *Health problem:* How shall I keep clean? What kind of clothes shall I wear in different kinds of weather?

b) *Social problem:* How can I make friends at school? How can I help in some community project?

c) *Science problem:* The lights have gone out in the house. How can we find out where the trouble is? How can we run the furnace so that it will supply the most heat and use the least coal?

d) *Recreation problem:* On a good Saturday afternoon shall I go to the movies or go for a hike? Shall I spend my money to go to a ball game or to buy stamps for my collection?

2. One example would be the invention of the airplane which brought new problems about:

a) Landing fields and landing-field equipment.

b) New kinds of light and strong materials for building planes.
c) Communication with planes.
d) Instruments for flying blind, etc.
e) Control of disease, because germs can be brought in quickly from one country to another or harmful insects can be carried by plane.
f) More powerful engines.
g) Better gasoline.

3. The following may be mentioned, although not all are discoveries of scientists: Cooking, smoking, salting, keeping cool, freezing, drying, canning.

4. Some of these problems about airplanes may be given:
a) Developing airplanes that will rise perpendicularly in the air.
b) Developing automatic pilots.
c) Developing methods of eliminating the ice hazard.
d) Overcoming the danger of fog.
e) Cutting down the rate of landing speed.

5. (a) Had to determine the causes, if possible.
b) If a living thing was the cause, had to learn:
  1) What kind it is.
  2) How and where it lives.
  3) What it does to cause the disease.
  4) How it gets from one person to another.
  5) How it can be destroyed. This in turn leads to the problem of germicides, etc., public health measures, studies of vaccines, etc.
c) If no living thing is the cause, many problems about the human body, about proper foods, etc., have had to be solved.

6. Lists will vary widely. Any reasonable problems are acceptable whether on the topics suggested or on others.

PROBLEM 2: HOW DO SCIENTISTS SOLVE PROBLEMS? (P. 15)

The purpose of this problem is to show pupils that problem-solving consists of various steps in thinking and that good thinking in everyday living is the same type of thinking that the scientist does.

In discussion, pupils should be led to tell how they have worked out solutions to problems. In many cases they will discover that they have been using the steps of scientific thinking. Thinking can be traced fairly well in the case of autos that won't run, drawers that won't open, door bells that fail to ring, electric lights that don't light, etc. The solutions of several such problems should be traced and analyzed in terms of the steps of scientific thinking.

The following main ideas are stressed:

1. A good thinker does definite things in solving his problems.

a) He defines his problem carefully so that he knows exactly what it is he is trying to discover.

b) He thinks of possible ways of solving the problem.

c) He chooses the method he thinks most likely to be successful.

d) He experiments with this method; that is, he tests his idea by trying it out.

2. A scientist does certain definite things while he is solving a problem.

a) He decides what it is he wants to do.

b) He thinks of a number of possible ways to solve the problem.

c) He chooses a method that he believes will work.

d) He experiments to see if his explanation or solution is the correct one.

e) If the experiment seems to show that the explanation is a good one, he tests the explanation by other experiments to be sure that the solution is correct.

3. You can believe what the scientist says because his conclusions have been tested for their truth by himself and by other scientists.

SELF-TESTING EXERCISES (P. 21). 1. See the main ideas listed in 2 above.

2. To prove; to make sure something is true.

3. Because good scientists have been trained to prove or test their discoveries in every possible way before announcing them.

4. To test their ideas, i.e., to see if their ideas are true.

5. The table shows how two problems are solved scientifically.

STEPS IN SOLVING A PROBLEM SCIENTIFICALLY	EXAMPLE OF KITE IN TREE (PP. 15-17)	EXAMPLE OF CROPS THAT DID NOT GROW WELL (PP. 18-20)
1) Decide exactly what the problem is.	To get the kite down without tearing it.	To find out why plants do not grow well in the same field year after year.
2) Think of all possible solutions.	Pull on string, throw sticks, etc.	Sow seeds different ways; bad weather; lack of minerals; lack of water, etc.
3) Decide which is the best solution.	Walk out on limb, holding on to upper limb far enough to shake kite loose.	Decided, for various reasons that lack of minerals was best solution.
4) Plan how to carry out the best solution and try the plan.	Climb the tree and work way out to kite, holding on to upper branch.	Planned how they would find out—tested soil and found a difference. This seemed to be a good explanation.
5) If plan works, problem is solved. If not, try something else.	Problem solved, since the kite was freed without being torn.	Tested further by adding minerals to soil, planting seeds and seeing how the plants compared with those grown before minerals added. Grew better and had proved his idea correct.

PROBLEMS TO SOLVE (P. 22). 1. (a) Why did the cake not turn out well, and how can I improve the next one?

b) Think of the things that could affect quality of cake, such as kinds of ingredients, amounts of ingredients, temperature of oven, length of time of baking, etc.

c) Decide which of the above was probably the cause of the poor cake.

d) Test conclusion by baking another cake, avoiding previous error.

e) If the cake is a success, you have probably found out what was wrong with the first cake. Repeated successes would prove point.

2. (a) Think of things that make it possible for a successful airplane to leave the ground.

b) Examine his airplane to see if it meets all these conditions.

c) Choose condition that probably needs changing, and change it.

d) Try this, and if the airplane still does not leave the ground, try the next most probable condition.

3. The following are a few of the possible answers: Catch a toad and handle it. Have others do same things. Watch to see if any warts appear. Ask people with warts whether they ever handled a toad. Consult doctors.

4. Responses should be checked against the usual steps of thinking, but a mere list of these steps, which does not show how they apply in the particular problem, is hardly satisfactory.

PROBLEM 3: HOW HAVE SCIENTIFIC INSTRUMENTS HELPED SCIENTISTS SOLVE PROBLEMS? (P. 23)

Many people look upon the findings of science with skepticism or with awe because these findings many times fail to coincide with the data from their own unaided senses. Furthermore, such people have no idea of the extreme sensitivity of scientific instruments and of the consequent accuracy of the results that may be obtained from using them. The self-testing exercises emphasize these ideas.

Have pupils secure, or observe, or report on observations of every possible aid to observation and recording of natural phenomena. There is no need to limit such work to the instruments named in the reading material. Get pupils to realize that they are themselves making daily use of such aids to observation and recording of observation as cameras, thermometers, balances (scales), weather vanes, barometers, hydrometers of various kinds, speedometers, gauges, clocks, yardsticks, etc.

The main ideas are:

1. Because of the invention of scientific apparatus to weigh and measure things it is possible to solve problems today that could not be solved hundreds of years ago.

2. Scientific instruments extend the range of our senses.

a) They make things visible that cannot be seen with the naked eye.

b) They weigh objects that cannot be weighed by our sense of weight.

c) They detect the presence of materials that cannot be detected by the senses.
d) They measure degrees of heat with great accuracy.
e) They enable the physician to tell what is going on inside the body.

3. The scientist can discover more facts than ordinary people because he has instruments that are much more sensitive than our unaided senses.

SELF-TESTING EXERCISES (P. 31). 1. Because he has many fine instruments to help him, which the earlier scientists did not have. He has new methods of using the instruments and making tests. Following up the idea of the treatment Galileo received—being laughed at and thrown into jail for his scientific ideas and experiments, it might be brought out that the changed attitude toward science in most places has helped the scientist in his work.

2. *Telescope* makes the stars and other heavenly bodies appear brighter or nearer.

Microscope makes objects appear larger when they are too small to be seen clearly by the naked eye, and makes some things visible which are too small to be visible to the naked eye.

Analytical balance weighs very small amounts of materials and makes it possible to discover very slight changes in weight.

Thermometer measures temperature of body, air, and other substances. Some kinds detect very slight changes in temperature.

Stethoscope enables doctor to hear heart beat and tells him things about condition of lungs.

X-ray enables doctor to examine organs and bones in body.

3. The scientist, for following reasons: (a) Has probably examined object more closely with aid of special instruments.
b) Has probably made tests to see if his observations and ideas about objects are true.
c) Probably has knowledge of similar objects which help him understand and explain this one.

PROBLEMS TO SOLVE (P. 32). 1. (a) Enables him to obtain a connected picture or account of an event or happening.
b) Enables him to study object or event carefully by making it possible for him to see it again and again.

c) Can show rapid movements very slowly.
d) Can show very slow changes very greatly speeded up.

Looking Back at Unit 1 (p. 32). Check pupils' papers against the main ideas stated on pages 61, 65, and 67-68 of this *Guidebook* for the three problems of this unit.

At this point in the study of the unit it is helpful to have a class discussion of the unit as a whole. The teacher may well ask, "What important new ideas did you get from the study of this unit?" If it seems best, each pupil may be asked to write down those that occur to him. Then, one by one, they are read to the class. The teacher may write them on the board until all new ones have been recorded. In some units the making of a diagram by the teacher, by the more rapid workers, or by all pupils is a desirable way of organizing the unit. (Refer to the unit graph on page 59.) Such activities constitute the organization of the unit. See pages 50-51.

Additional Exercises (p. 33). Pupils who have time and ability and who have a real contribution to make to the class should be encouraged to report to the class their work on one or more of these exercises.

1-6. Answers will vary with pupils. Since the work on such exercises is usually voluntary, a wide latitude of accomplishment may be accepted, but pupils should be encouraged to use their own initiative and to do the best of which they are capable. Attempts that do not represent real effort and accomplishment for the individual should not be too highly praised.

7. Test by filling both with boiling water or with ice water and allowing them to stand for same length of time. At end of time see in which bottle the water has remained hotter or colder, as the case may be.

9. Stand the ruler upright in a certain spot in the sunlight at noon on a summer day. Mark the length of the shadow on the ground and with the ruler measure it. Repeat at noon on a winter day and compare lengths of shadows. Of course, the winter observation can be taken first. Many variations of this procedure are possible.

10. Keep record of direction of wind and of times it rains and see from which direction the wind usually blows just before it rains. If one direction of wind seems most common, notice whether the wind continues from that direction while it is raining.

VISUAL MATERIALS FOR UNIT 1

As motion pictures, slides, filmstrips, photographs, charts, etc., contribute much toward making science instruction more meaningful to pupils, a few selections have been made for most of the units. In Part Four, Publications and Teaching Materials for the Science Teacher, there are lists of sources of these materials.

MOTION PICTURES

Bakelite Corporation, 247 Park Ave., New York, N. Y.
 "Science Saves the Surface" (free)
Bausch & Lomb Optical Company, Rochester, N. Y.
 "The Eyes of Science"
 "Glass Magic" (free through local B & L dealers)
Du Pont Company, Motion Pictures Bureau, Wilmington, Del.
 "A New World Through Chemistry" (transportation charge)
Eastman Classroom Films, Rochester, N. Y.
 "Historical Introduction to the Study of Chemistry"

PHOTOGRAPHS

Science Service, 21st and B Sts., Washington, D. C.
 Photographs of scientists (A catalog will be sent.)

UNIT 2

What Kind of World Do You Live in?

FUNCTION AND SCOPE OF UNIT 2. The major purpose of this unit is to give the pupil a bird's-eye view of the world in which he lives so that he may see the kinds of problems that each aspect of the world presents. (The unit graph on page 72 will help focus on the unit as a whole.) The unit is also designed to give the pupil a clearer idea of the nature of the subject matter in the field of science. Since the different problems are merely an overview of some aspect of the environment, the teacher must be careful not to overelaborate the study material. The purpose of the unit is to raise problems and to show the pupil where he is going rather than to present a body of subject matter to be learned.

Where possible, this unit may well be introduced by a "field trip." Take the pupils outdoors. Ask them to separate and sit down to make an inventory of all the kinds of things, natural happenings, forces, etc., they notice—sounds, light, odors, rocks, soil, wind, sun, living things. Let them include things they have previously noticed that come to mind. Suggest that they think of night as well as day. They may later compare their lists or make up a long list for the class. As they read the unit in the textbook, each pupil may classify his own list by using marks according to a "key." At the end of the study of the unit, each pupil should have a mental picture of the world as a whole. This should then serve as a framework to which to attach mentally the details discovered as the study of later units is undertaken.

INTRODUCTORY EXERCISES (P. 36). 2. The following are possible answers: *Wood.* (a) Houses, telegraph poles, paper, furniture. (b) Natural.

Tin. (a) Utensils, tinfoil, roofing. (b) Made from tin oxide mined as an ore.

Iron. (a) Engines, bridges, pipes, stoves. (b) Prepared from iron ore, largely iron oxide.

Steel. (a) Auto bodies, wire, railroad tracks, framework for

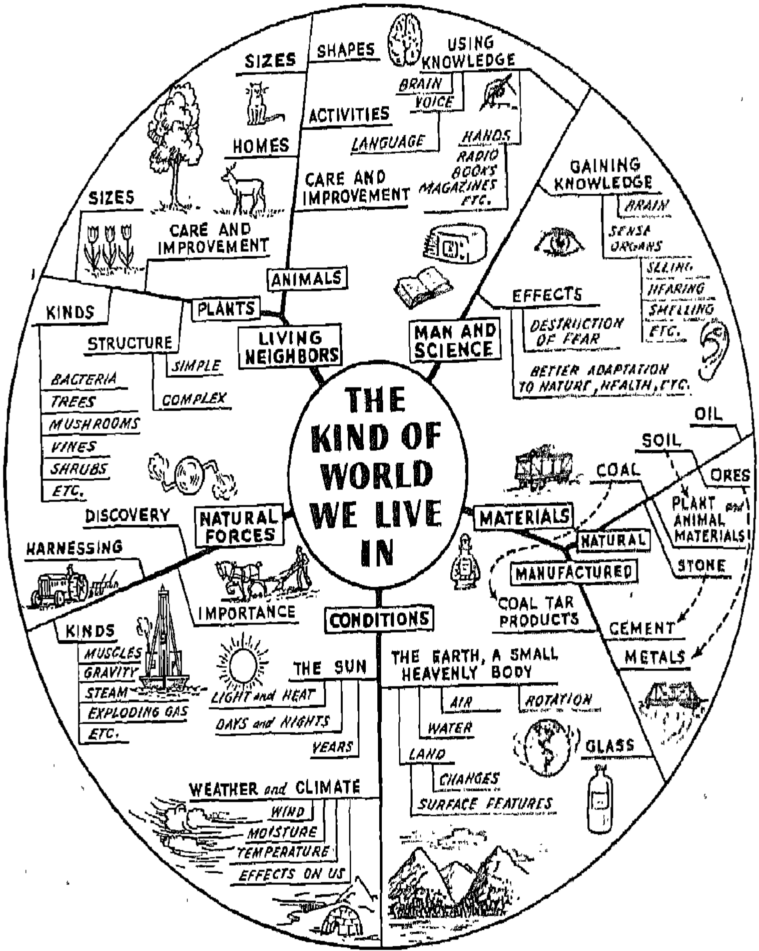

FIG. 2. GRAPH OF THE SUBJECT MATTER OF UNIT 2

buildings, cutlery, hulls of ships, surgical instruments. (*b*) Made from iron by adding correct amount of carbon and other substances.

Copper. (*a*) Kettles, pennies, copper-plating, wire, roofing, bottoms of ships. (*b*) Found as free copper or extracted from ore.

Silk. (*a*) Clothes, household decorations, umbrellas. (*b*) Made from thread spun by silkworm when it makes a cocoon.

Linen. (*a*) Clothes, bed and table linen. (*b*) Made from fibers of flax plant.

Silver. (*a*) Money, dishes, jewelry, tableware, photographic film. (*b*) Extracted from silver ores.

Cellophane. (*a*) Wrappings. (*b*) Made by men from plants.

Aluminum. (*a*) Kitchen utensils, dishes, framework, airplane parts, furniture, cosmetic tubes. (*b*) Prepared from clay containing aluminum.

5. Some of the forces that may be named are: Running water, wind, gravity, steam, electricity, exploding gases.

6. Man can understand the forces and materials in the world, use them for his own convenience, change or direct the forces and materials into other kinds of forces and materials. He can do these things because he has a brain.

LOOKING AHEAD TO UNIT 2 (P. 37). The preview introduces the five topics under which we can study the world we live in: conditions, materials, living neighbors, forces, and human beings. The pupils should be directed to read the section and think about some questions they would like to have answered about each of the five topics. In the discussion that follows the five topics may be listed upon the board, and pupils may state the questions that have occurred to them. The kinds of questions asked will indicate whether or not the pupils have caught the general nature of each aspect of the world to be studied.

PROBLEM 1: WHAT CONDITIONS SURROUND US ON EARTH? (P. 41)

This problem shows that the relationships between the earth and the sun produce certain effects upon the earth and that these effects, combined with differences in the earth's surface at various places, result in conditions that determine the way we live. There should be *no* attempt at this time to go into detail regarding the universe, the cause of day and night, and the causes of the seasons. These concepts are covered in Unit 1 of *Book 2.* The changing of the earth's surface is covered in Unit 3, *Book 2.* Weather is covered in Unit 7, *Book 2.*

Following are the main ideas stressed in this problem:

1. The earth is a comparatively small ball among many other heavenly bodies that make up the universe.

2. The earth consists of solid soil and rock, of the air above its surface, and of water on its surface.

3. The features of the earth's surface and the changes they are undergoing are an important part of the conditions that govern our lives.

4. The conditions of temperature and light that surround us are governed largely by the earth's relationship to the sun.

5. The air conditions (resulting in changes in temperature, rain, wind) from day to day make up weather. The average of the weather in any part of the world is called climate.

6. We live the way we do because of the conditions that surround us on earth.

7. We study science in order to understand nature, but with all our knowledge we cannot change the major conditions of our surroundings.

SELF-TESTING EXERCISES (P. 49). 1. Pupil's answers should include these points: (*a*) A sphere, or ball, 8000 miles in diameter. (*b*) Consists of a solid part whose surface varies greatly, a liquid part, and an air covering. (*c*) The physical aspects are constantly changing.

2. (*a*) There would be no year as we now know it, because a year is based on the time it takes the earth to go around the sun. Pupils may recall from their geography that seasons are in part caused by the revolution of the earth around the sun.

b) No alteration of day or night every 24 hours. Light and excessively hot on one side but dark and cold on the other, since one side of earth would face the sun for long periods.

c) So cold that life as we know it couldn't exist.

d) So hot that no living things as we know them could exist.

3. (*a*) Changes in temperature. (*b*) Changes in speed and direction of wind. (*c*) Changes in amount of rainfall and snowfall.

4. *Many differences, similar to the following, may be listed.* *a*) In a very hot climate: (*1*) Would wear fewer clothes; (*2*) would have different kinds of houses, which would not need to be heated; (*3*) would not have to plan so carefully on growing season to be sure of adequate food supply; (*4*) would need different kinds of food. *b*) In a very cold climate: (*1*) Would wear much heavier clothes; (*2*) would have warmer houses; (*3*) would have to spend much more time and energy to obtain food; (*4*) would have different kinds of food—more meats and things that were hunted rather than grown.

5. The following are only a few of the possible answers: (*a*) Heating devices to heat homes in winter.
b) Cooling devices to cool buildings in summer.
c) Waterproof homes as protection from rain and snow.
d) Warm clothes for winter and cool ones for summer.
e) Food plants grown in greenhouses in winter.
f) Lights for long winter nights.
g) Heaters for automobiles.
h) Snow plows for roads.

PROBLEM 2: WHAT MATERIALS DO WE FIND IN OUR WORLD? (P. 49)

This problem presents an overview of the kinds of materials we have and of how the scientist utilizes these materials. Following are the main ideas of the problem:

1. There are over 300,000 different kinds of materials found naturally in the earth or that scientists now know how to make from materials found in the earth. (NOTE: It is not important for pupils to remember the number 300,000, as it is constantly changing.)

2. The use of the natural materials provided by the earth increased with great rapidity when man learned how to study the earth scientifically.

3. Scientists do four important things with materials: (*a*) They discover new materials.
b) They find out what materials are made of.

c) They find out how to take materials apart, so that two or more materials may be obtained from one material.
d) They experiment by putting together different materials to make new and different materials.

SELF-TESTING EXERCISES (P. 56). 1. These four things are listed in the third main idea, beginning on page 75.

2. (*a*) Better methods of discovering new materials.
b) Better methods of discovering what different materials are made of and what they will do under different conditions.
c) Better methods of combining materials to make other new ones.

3. Some of the columns in this table include only representative materials.

BUILDING MATERIALS	FUELS	CLOTHING MATERIALS	CHEMICALS	MISCELLANEOUS
Wood, N	Gasoline, M	Cotton cloth, M	Baking powder, M	Cellophane, M
Cement, M	Kerosene, M	Linen cloth, M	Salt, N	Bakelite, M
Brick, M	Wood, N	Wood, M	Acids, M	Chromium, M
Slate, N	Coal, N	Silk, M	Hydrogen peroxide, M	Aluminum, M
Stone, N	Peat, N	Furs, N	Iodine, M	
Marble, N	Crude oil, N	Leather, N	Ammonia, M	
Steel, M	Gas, N and M	Rubber, M		
Iron, M				
Glass, M				

4. The answers will vary with the individual. (*a*) In *chemistry* we study about materials and the substances of which they are made.
b) *Natural materials* are those that are used as they are found in or on the earth.

PROBLEM 3: WHAT LIVING NEIGHBORS DO WE HAVE? (P. 57)

This problem emphasizes the great differences among living things and the dependence of man upon living things. Following are the main ideas:

1. There are over 800,000 different kinds of animals and 225,000 different kinds of plants. (NOTE: It is not important

for pupils to remember the specific numbers, as they are constantly changing.)

2. Plants and animals range in size from very small to very large, and in structure from simple to complex.

3. Man uses living things for food and clothing.

4. Man has been able to improve living things for his own purposes by solving problems about how they grow, what kinds of food are best for them, how much light, heat, and moisture they need, and how to cure their diseases.

Self-Testing Exercises (p. 64). 2. Some problems that may be listed are: (*a*) How do plants grow? (*b*) What kinds of food do plants need? (*c*) How much light and heat do plants need? (*d*) How much moisture do plants need? (*e*) What diseases do plants have, and how can they be cured?

3. Some ways that may be listed are: (*a*) Larger animals as meat producers.

b) Larger and more powerful animals to do his work.
c) Animals that grow better wool for clothing.
d) Larger and juicier fruits.
e) Plants and animals that resist attacks by parasites.

4. A biologist is a scientist who studies living things.

5. Bacteria are the smallest plants; some make us ill and others help us.

6. Many differences may be given. The following are fundamental to scientists: (*a*) Has no true root, stem, leaves, or flowers.
b) Not green—does not make its own food.
c) Reproduces by means of spores instead of seeds.

7. Yes.

8. Five fields of difference are given; others are possible: (*a*) size; (*b*) shape; (*c*) places where they can live; (*d*) kind of food; (*e*) kind of climate (temperature) in which they can live.

PROBLEM 4: WHAT NATURAL FORCES DO WE USE? (P. 65)

This problem shows how man multiplies his own force through the use of natural forces and thus is able to increase greatly the amount of work that can be done. Following are the main ideas:

1. Nothing in this world moves unless it is pulled or pushed by some kind of force.
2. Gravity is the force that keeps us from falling off the earth and that brings objects above the earth to the earth if they are not supported.
3. Man learned to harness the force of steam and to use it to drive engines.
4. About 50 years ago man harnessed electricity so that it could do many kinds of work.
5. About 50 years ago man learned how to use the force of exploding gas to run machines.
6. When man learned to harness the forces of nature, he was able to multiply his own force and thus increase the amount of work that could be done.
7. The harnessing of the forces of nature has greatly changed our world and made it a different place in which to live.

SELF-TESTING EXERCISES (P. 70). 1. Ideas that should be included are what would happen if there were no gravity, no wind, no force of muscles, no steam, no electricity, and no exploding gas.

2. (a) Gravity, (b) wind, (c) force of muscles.

3. (a) Steam, (b) electricity, (c) exploding gas.

4. Gravity. Examples of use may include playing ball, coasting downhill, sailing a sailboat, etc.

5. Gravity. Pupils may also see that some force is used in lifting the weight, but what that force is is not specified in the exercise. Answers will vary, but may well include the following:

WATER-WHEEL	WINDMILL	STEAM ENGINE	ELECTRIC MOTOR	GASOLINE ENGINE
Dynamos Sawmills Running grist mills	Water pumps Small electric generators in farmhouses	Trains Boats Steam shovels	Refrigerators Sewing machines Streetcars Washing machines Railroad trains	Automobiles Airplanes Motorboats

PROBLEM 5: WHAT KIND OF BODY DOES MAN HAVE? (P. 71)

The purpose of this problem is to show pupils that man has been able to do the things he can do because of the kind of body he has. Man is superior to other animals because he has useful fingers and a brain that enables him to understand nature and direct his activities toward better adaptation to it. Following are the main ideas of the unit:

1. Man has sense organs that inform him of what is going on inside his body, on the surface of his body, and at places distant from his body.

2. The sense organs of man are not necessarily superior to those of other animals.

3. Man has skillful fingers which he can use to do things that other animals cannot do.

4. Man is superior to the other animals because he possesses a brain that enables him to think, plan, and solve problems and that frees him from fear.

a) Man's brain is used to direct his nimble fingers.
b) Man can communicate his discoveries to others and can hear or read about the discoveries of others.
c) What man learns can be passed on to the next generations.
d) Man can devise tools to help him do his work.
e) Man can devise methods of protecting himself from conditions of cold and heat.

5. Man has not conquered nature; he has only discovered its laws and used these laws for his own benefit.

SELF-TESTING EXERCISES (P. 76). 1. Lists will vary, but should include points emphasized in reading material. (a) Can hear, see, feel, smell, and taste because of sense organs.
b) Can use fingers to do many things.
c) Can think and plan because of the brain.
d) Can communicate with others by written and spoken language.
e) Can understand the world about it, thus becoming less afraid.
2. (a) Has fingers that can grasp and use tools.
b) Has a brain that can think and plan and study.

3. (*a*) Some sense organs are better developed in some animals, especially those of smell.
b) Supplied with covering so that they do not have to protect themselves from changes in climate.
c) Can get food without use of tools or implements.
d) Some of them can move more rapidly.

4. (*a*) One can recognize things or figure out how to find someone without having to depend on the senses.
b) Man can make clothes from many kinds of materials and figure out how to obtain these materials from different sources; he can build better homes.
c) Man can make weapons and instruments to obtain food; he can grow things for use as food; he can raise animals; he can prepare many different kinds of food from the materials he grows or raises.
d) Man can devise weapons to protect himself from other animals or to capture them.

5. (*a*) To get proper amount of sleep; (*b*) to eat the correct food.

Pupil may well add points that are not made in text: (*a*) To keep clean; (*b*) to exercise enough; (*c*) to be out in the sun and air as much as possible; (*d*) to protect himself from disease germs.

LOOKING BACK AT UNIT 2 (P. 76). Diagram to be made by students.

VISUAL MATERIALS FOR UNIT 2

MOTION PICTURES

Eastman Classroom Films, Rochester, N. Y.
  "The Automobile" (interdependence of industries)
  "Iron Ore to Pig Iron"
  "Aluminum"
Erpi Classroom Films, Inc., 35-11 35th Ave., Long Island City, N. Y.
  "Animal Life"; "Animals in Modern Life"
Northern Pacific Railway Company, Passenger Traffic Department, St. Paul, Minn. (Free travel and scenic pictures)
Reading Iron Company, 401 W. Broadway, Philadelphia, Pa.
  "Metal of the Ages" (free)
Viscose Company, 171 Madison Ave., New York, N. Y.
  "Romance of Rayon" (free)

UNIT 3

What Is a Material?

FUNCTION AND SCOPE OF UNIT 3. Most of us take our everyday surroundings so much for granted that we fail to notice any puzzles or problems that need to be solved—we do not consciously notice significant similarities and distinctions and use them in our thinking.

This unit deals with aspects of the environment that are very familiar to every youngster—solids, liquids, gases, how they are alike, how they differ from one another, the real nature and the importance of solutions. It is planned to help pupils develop the habit of thinking critically about common things and to give practice in simple abstractions. At the same time the concepts developed by the activities provided and the new ideas introduced are useful in everyday life and in later units in the course. The graph on page 82 will help the teacher select the points to be emphasized in the study of the unit.

Problem 2 of Unit 2 has presumably made pupils aware of the following general facts: (1) There are many different kinds of materials all about us. (2) By trial-and-error methods and by the application of science man has obtained many new kinds of materials from natural materials. (3) Man's use of both natural and artificial materials has made great differences in the way we live.

Unit 3 has been planned to stimulate thought about the essential similarities and differences in the materials to which pupils' thoughts were directed in Problem 2: How are all materials alike? Is air really a material? How do we know? How is a liquid different from a solid? What is a gas? What is a solution? How is it different from any other liquid mixture? Such questions, thoughtfully and leisurely discussed and answered with the help of their own observations, will modify the attitudes of pupils toward their surroundings. They also help in further study, as indicated in the units listed on page 83.

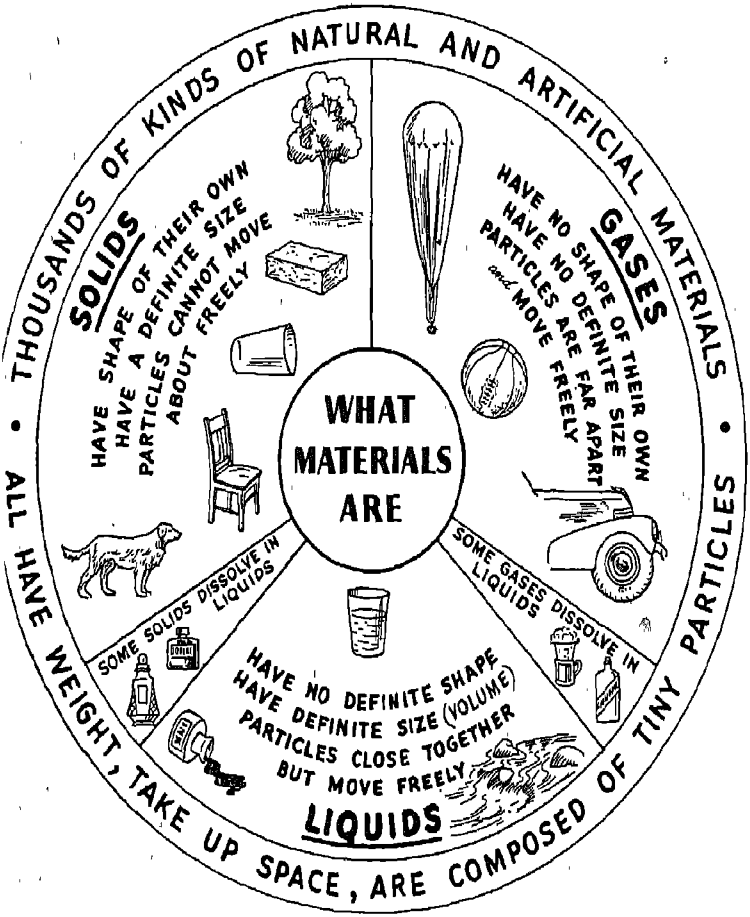
THOUSANDS OF KINDS OF NATURAL AND ARTIFICIAL MATERIALS
ALL HAVE WEIGHT, TAKE UP SPACE, ARE COMPOSED OF TINY PARTICLES
WHAT MATERIALS ARE
SOLIDS
HAVE SHAPE OF THEIR OWN
HAVE A DEFINITE SIZE
PARTICLES CANNOT MOVE ABOUT FREELY
GASES
HAVE NO SHAPE OF THEIR OWN
HAVE NO DEFINITE SIZE
PARTICLES ARE FAR APART and MOVE FREELY
LIQUIDS
HAVE NO DEFINITE SHAPE
HAVE DEFINITE SIZE (VOLUME)
PARTICLES CLOSE TOGETHER BUT MOVE FREELY
SOME SOLIDS DISSOLVE IN LIQUIDS
SOME GASES DISSOLVE IN LIQUIDS

FIG. 3. GRAPH OF THE SUBJECT MATTER OF UNIT 3

Unit 4. "How Do Heating and Cooling Change Materials?" Changes of state. Explanation of expansion and contraction in terms of the tiny particles in substances.

Unit 5. "How Can One Kind of Substance Change into Another Kind?" An added characteristic of all materials: They are composed of elements. Chemical changes are rearrangements of the elements in compounds. Chemical changes involve changes in the particles that make up substances.

Units 9-11. "How Do Plants and Animals Get Food?" "Why Do We Eat Different Kinds of Food?" and "How Do Plants and Animals Live Together?" Living things are composed of materials and are constantly taking in and giving out solids, liquids, and gases. Without solutions of food, oxygen, carbon dioxide, and other substances living things could not exist.

INTRODUCTORY EXERCISES (P. 78). 1. In shape, weight, color, size, what they are made of, etc.

2. Take up space, have weight, have definite shape, and have definite size. (To say that both are solids is only saying that both have definite shape and size.)

3. Does not have shape of its own. (Pupils will probably say that liquids are clear, wet, etc. Discussion may well bring out the facts that some liquids are not clear, some are not "wet"—mercury, etc.)

4. Take up space and have weight.

5. Yes. It takes up space and has weight.

6. We mean that it has been put into a liquid, has separated into pieces that are too small to be seen even with a microscope, and has mixed thoroughly with the liquid. (To say that "it has formed a solution" or "has become a liquid" is hardly a meaningful answer.)

7. Less. This is true because the tire contains more air when it is full, and air has weight.

LOOKING AHEAD TO UNIT 3 (P. 79). The main purpose of the introductory activities (Introductory Exercises and Looking Ahead, or preview) is to get the pupils into an interested, inquiring, and observing attitude toward the materials about them. Any teaching devices that help the teacher accomplish this end should be utilized. Effective use can be made of the Introductory Exercises and many more similar questions.

"What different kinds of materials do you know?" will lead the pupils to list kinds of material. The list soon becomes ridiculously long. In case the pupils do not include liquids and gases, leading questions by the teacher will, in most cases, produce examples of each. "Which of these materials are alike?" will start the pupils classifying the materials in the list. The results will be very similar to the scientist's classification into solids, liquids, and gases.

Questions about the kinds of liquids help lay the groundwork for the problem on solutions and other types of mixtures in liquids. Quite in place also are questions such as the following: What do you think is in ....? What is .... made of? If we begin dividing .... into smaller and smaller pieces, what would we finally get? Do you think the air is in little pieces? If there are tiny pieces in the air, are they far apart or close together?

With a list of different materials on the blackboard and a preliminary classification suggested, the teacher may ask the question which serves as Problem 1, "How are all materials alike?" In most classes this alone will start a string of suggestions out of which the teacher may help the pupils abstract the essentials of the solution of the problem even before the pupils have done any reading at all.

If the unit has been introduced as outlined above, the reading material on "Looking Ahead" may serve only as a review of the inquiries the class has made and as make-up work for pupils who may have been absent.

Another type of introduction is, of course, the mere reading of the preview and a brief discussion of it to make sure that the pupils have understood what they have read. However, it should be remembered that detailed quizzing on the statements of the preview is distinctly out of place and may result in killing any spirit of interest that its reading has generated. Usually it will be best to go right on to the reading of Problem 1 in order to find the answers to the questions that are in the pupils' minds.

Whether the teacher leads the pupils naturally into the problems of this unit by questioning and discussion or has them read the preview as it is given in the textbook, his purpose is the same: to get the pupils to thinking critically about the many materials around them and to wondering how they are alike, how they may be classified, and what they are really composed of.

PROBLEM 1: HOW ARE ALL MATERIALS ALIKE? (P. 81)

In individual development, as in the development of "science," a great step has been made when the boy or girl learns to strip any situation or any class of things to its essentials and thereafter use those essentials in his thinking. Consideration of Problem 1 is intended to help boys and girls begin to develop the concept of matter as one of the two great divisions of the universe that are concerned in every aspect of the natural world. (Scientists believe that all phenomena involve matter and energy.) Some pupils will gain this concept during their study of the problem, or will have gained it before they begin; others will develop it gradually after this emphatic introduction.

Boys and girls quickly see that solids and liquids have some characteristics in common. They do not so readily feel that air has these same characteristics. Thus the teacher's major effort in the study of Problem 1 is to help pupils realize, if they do not already do so, that a gas is just as real as a solid or a liquid and has some of the same characteristics. (In addition to the characteristics stressed in this problem, all matter has inertia. Some good thinkers or advanced pupils may discover this additional characteristic. If so, and if the class becomes interested, there is no harm in stressing it and in using it in future discussion; otherwise do not attempt to discuss it at this time.)

The main ideas of Problem 1 are as follows:

1. All materials have weight.
2. All materials fill up space.
3. Air has weight and fills space; it (along with other gases) is just as truly a material as wood and water.

EXPERIMENT 1. DOES AIR HAVE WEIGHT? (P. 82). The apparatus and materials needed for this experiment are:

- Football or basketball (or any other kind of large ball that can be inflated; preferably with a non-elastic cover)
- Air pump, type suitable for inflating ball
- Rubber band or string (some device to keep air in ball)
- Balance, fairly sensitive
- Weights, sand, small pieces of paper or tin-foil for counterbalancing the deflated ball

This experiment is best carried out as a demonstration by the teacher or by a group of pupils who can try it out in advance of the class demonstration. The use of such everyday apparatus as a tire pump and a basketball helps make pupils feel that the results are real.

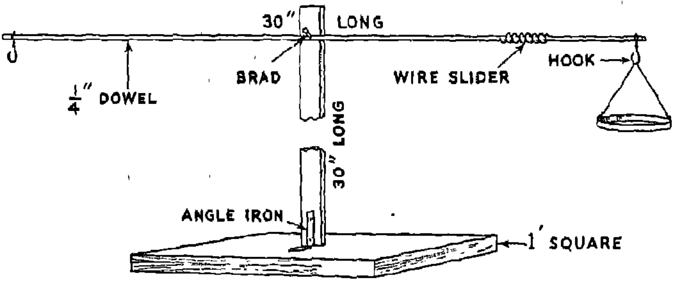

FIG. 4. A HOMEMADE BALANCE*

Any reasonably sensitive balance gives striking results. A homemade one may be made, as shown in Figure 4. If the homemade balance is used, some satisfactory way of hanging the ball on the wire hook must be devised, and care must be taken to have exactly the same articles on the balance with the ball before and after it is inflated.

Keeping the right kinds of records of experiments gives pupils valuable training in description and helps them observe and think clearly about the experiments. A certain number of the earlier experiments in the course should be written up with care. The pupils' accounts should be rather carefully checked by the teacher to insure that a correct start be made. When pupils have mastered the necessary skill in observing, writing, and interpreting, many of the experiments, especially the simpler ones, may be done without requiring written accounts. It is highly desirable that, as soon as possible, pupils learn to watch and to remember the results of experiments without the artificial stimulus of a required "write-up."

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* Adapted from the figure on page 335 of an article in *School Science and Mathematics*, April, 1941.

Pupils will think more clearly about the experiment if it is divided into four definite parts: (1) The question or problem to be answered. (2) What we did (how we asked nature the question). (3) What happened (the answer nature gave). (4) What the results show (what nature's answer means). Teachers will at once recognize here the traditional division into purpose, procedure, results, and conclusion, but pupils understand the suggested headings much better. As a result, they make the desired distinctions more clearly.

EXPERIMENT 2. DOES AIR TAKE UP SPACE? (P. 84). The apparatus and materials needed for this experiment are:

Pan or jar, three or four inches deep
Glass tumbler (or half-pint jar or beaker)
Flat cork or piece of wood, smaller than inside of tumbler
Water

This experiment can be done successfully by the pupils themselves, either individually or in small groups. The cork or wood is used to show clearly the level of the water surface inside the inverted tumbler. There are almost always a number of pupils who have never noticed that water does not ordinarily rise to its own level inside a closed vessel. Care should be taken to make sure that all pupils actually see what happens. It will be well to have at hand a glass vessel of some kind (bottomless jar, test-tube with broken bottom, or open glass cylinder) that can be placed in the water beside the inverted tumbler. Comparison of the results in the two cases will then be sure to bring out the significant effect of the air confined in the closed vessel.

SELF-TESTING EXERCISES (P. 85). 1. (*a*) Have weight; (*b*) take up space.

2. Describe Experiment 1 (p. 82) or a similar one. Most simple experiments to show that air has weight are either variations of Experiment 1 (pumping more air into a container and showing a gain in weight) or of the opposite procedure in which a container full of air is counterbalanced and then air is pumped out with a vacuum pump.

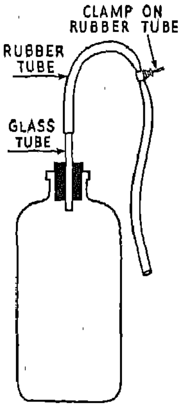

FIG. 5

3. Describe Experiment 2 (p. 84) or a similar one, such as attempting to pour water into a bottle without letting the air escape.

4. Boys and girls need much practice in finding and stating the reasons for the views they accept. Self-testing exercises 4 and 5 give practice of this kind. Any good reasons that pupils can give in support of their belief should be accepted. The following are some of the reasons that may be stated:

a) I can put only so much wood, or water, or air in a certain space.

b) This has always been true for me, and I think it is probably true in all cases.

c) The authors of my science book say it is true.

d) My teacher says it is true.

5. The reasons given will be similar to those for exercise 4.

PROBLEMS TO SOLVE (P. 85). 1. Figure 5 shows how to set up the apparatus. (a) Fit bottle with stopper, rubber tube, and clamp to close tube.

b) Weigh and record weight.

c) Attach tube to vacuum pump, open clamp, and pump air from bottle.

d) When air is removed, close clamp and weigh again. The bottle should be lighter.

The procedure can be reversed and will work even better. Pump air out and close tube. Remove from pump and place on balances. Add weight to opposite side until both sides are equal. Then let air enter bottle again and see whether it gets heavier.

2. The solution to this problem is based on a realization that air occupies space and that if the air is removed from a space (such as that in Tumbler A, Figure 68), water will enter. To solve the problem, use a rubber tube of some kind. Blow air under edge of B until tumbler is full of air. Then insert tube into Tumbler A and "suck" air from that glass.

3. Place bottles under water and remove stoppers. Water will enter the one that contains no air and will not enter the other until a bubble of air has left it. Other solutions are possible, such as loosening the stopper and noticing whether there is a hiss of entering air, but the answer is not so sure to be conclusive as in the first solution. If it be assumed that the weights of the two bottles are exactly the same, the problem can be solved by weighing the bottles. However, this assumption should be clearly stated, since it does not appear in the statement of the problem.

PROBLEM 2: WHAT ARE SOLIDS, LIQUIDS, AND GASES? (P. 86)

Thinking and communication, in science and everywhere else, involve classification. A recognition of the essential characteristics of the classes in which we place things is necessary for clear and accurate thinking. The materials of our environment provide easy practice material for classification. With some guidance by the teacher many groups of pupils can be led to work out the elementary classification of materials into solids, liquids, and gases and to state some of the peculiar characteristics of each class. If possible, this should be done before the pupils read the discussion of Problem 2 in their textbooks. Some suggestions of how this project may be carried out are given in the discussion of "Looking Ahead to Unit 3," page 84.

The main ideas that should be developed are:

1. Materials are classified as solids, liquids, or gases because of differences in their characteristics.

2. A body of solid material occupies a certain amount of space (has a definite size) and holds its shape.

3. A certain amount of a liquid fills a definite amount of space but takes the shape of its container.

4. A certain amount of gas fills whatever space is open to it. (It is recognized that some of these statements are true only when conditions remain constant.)

SELF-TESTING EXERCISES (P. 89). 1. The following tabular form is called for:

A SOLID	A LIQUID	A GAS
Takes up space. Has a definite size. Has weight. Has a definite shape.	Takes up space. Has a definite size. Has weight. Takes the shape of the container that holds it. Has no definite shape.	Takes up space. Has no definite size. Has weight. Takes the shape of the container that holds it. Has no definite shape. Fills any vessel in which it is put.

2. If pupils do not see that they can use their answers to exercise 1 for exercise 2, that fact should be pointed out to them.

a) A solid has definite shape of its own; a liquid does not.

b) A solid has definite size and shape; a gas has neither.

c) A liquid fills a certain part of the container that holds it; a gas fills all the space that is open to it.

3. A tabular form might be used. (a) *Solids:* Iron, glass, paper, sponge. (b) *Liquids:* Milk, honey, oil, vinegar. (c) *Gases:* Air, oxygen.

PROBLEMS TO SOLVE (P. 90). 1. In Figure A the particles of air should be evenly distributed throughout the bottle and not bunched together in clumps.

2. In Figure B the particles should be evenly distributed throughout the bottle and not clustered more thickly in the lower part.

3. In Figure C the surface of the liquid should be horizontal.

4. Figure D shows an increase in the volume of water when it is poured into the pan. This cannot be. The water poured from the glass should form only a shallow layer in the bottom of the pan.

5. In Figure E the particles shown in bottle 2 should be evenly distributed throughout both bottles when the empty one is inverted above it.

6. In Figure F the surface of the water should be higher after the ball is put in. All matter fills space.

PROBLEM 3: WHAT IS A SOLUTION? (P. 91)

Some realization of the nature of the liquid mixtures called solutions and of the fact that gases as well as solids dissolve in liquids is necessary to avoid careless and confused thinking about different types of liquids with which people come in contact every day. Straight thinking about these points leads to better management of practical details connected with liquids. The main ideas developed in answer to the problem are:

1. Solutions play a very important part in everyday life.
2. Any solution has certain definite characteristics.

a) The dissolved particles are invisible; the solution is clear even though it may be colored.

b) The dissolved particles pass with the liquid through any filter.

c) The dissolved particles remain evenly scattered throughout the liquid.

3. Gases often dissolve in liquids.
4. A substance that will not dissolve in one liquid may dissolve easily in another.

EXPERIMENT 3. WHAT ARE THE CHARACTERISTICS OF A SOLUTION? (P. 92). The apparatus and materials needed are:

Three medium-sized glass beakers (or tumblers)
Three test-tubes
Three six-inch circles of filter paper (or fine towel paper)
Funnel, glass or metal
Ringstand with ring to hold funnel (or other support)
Two pints hot water
Teaspoon tea leaves
Teaspoon sugar
Lump copper sulphate

The procedures called for in this experiment can readily be carried out by pupils at school or at home. Other soluble substances may be used. Three pupil committees of two or three members each may be formed, one committee to prepare and exhibit each of the three solutions called for. A fourth committee should do Experiment 4 and demonstrate and report on it at as nearly the same time as possible. Only one of the filtrations need be demonstrated to the class.

All three of the characteristics of solutions emphasized in the text should become evident to pupils from this experiment. If the solutions are examined with a microscope, the teacher should set up the microscope and focus it on the liquid. This may be done most easily by focusing on the edge of the drop and moving the slide to bring the center part of the drop under the microscope. Care must be taken to have a clear solution without sediment. This may usually be obtained by allowing the liquid to settle for a short time and taking the drop from just under the surface; otherwise, bits of lint or dust may be mistaken for particles of the dissolved material.

Experiment 4. How Do We Know That a Mixture of Starch and Water Is Not a Solution? (p. 95). The apparatus and materials needed are:

Medium-sized glass beaker (or tumbler)
Two test-tubes (or other small receptacles)
Small funnel, glass or metal
One-half pint water
Six-inch circle of filter paper (or fine towel paper)
One-half teaspoon laundry starch
Ten drops dilute iodine solution

The iodine solution may be made by adding tincture of iodine to water until the water is distinctly brown.

The procedure of this experiment is much the same as that for Experiment 3. If a microscope is available, the starch mixture may be examined with it. Starch grains should be easily visible. Special attention may well be given to the chemical test for starch that is introduced in this experiment.

It should be noted that very finely divided, but insoluble, solids such as those in milk and India ink are able to pass through a paper filter. Examination with the high power of a microscope will reveal visible particles in both these substances. The particles of dissolved materials are always invisibly small.

EXPERIMENT 5. HOW CAN WE DISSOLVE MATERIALS THAT DO NOT DISSOLVE IN WATER? (P. 97). The apparatus and materials called for are:

Gum camphor
Teaspoon butter or lard
Water
Alcohol
Carbon tetrachloride
Five test-tubes
Jar (or test-tube rack) to hold tubes upright

The gum camphor, obtainable from drug stores, should be kept in a glass-stoppered bottle or tightly covered tin can to prevent evaporation.

a) Camphor dissolves in alcohol. The product is "spirits of camphor" to be found in many medicine cabinets.

b) This part of the experiment works better with lard than with butter, because water and milk solids in the butter cause cloudiness in some of the liquids that really dissolve the fat of the butter. Be careful not to use quantities of camphor and fat that are too great to be dissolved in their solvents. Carbon tetrachloride is a good fat solvent. The effectiveness of the alcohol depends in part on how high a percentage of the alcohol mixture is water.

NOTE: The teacher may want to supplement part *b* by placing a piece of lard in a test-tube half full of gasoline. Gasoline must be kept and handled with great care. It also is a good fat solvent.

SELF-TESTING EXERCISES (P. 100). 1. (a) The liquid is clear; particles of the dissolved solid cannot be seen.
b) The particles are so small that they pass through filter paper.
c) The particles remain scattered all through the liquid, even when the liquid is allowed to stand for several days.

2. (a) The liquid is cloudy.
b) The starch does not pass through the filter paper.
c) The starch settles to the bottom of the liquid.

3. In a solution the particles of the dissolved solid are too small to be seen.

4. Pupils may give some of these examples (two are called for):
a) Carbon dioxide dissolved in carbonated soft drinks and charged water.
b) Air dissolved in water.
c) Chlorine dissolved in water to kill bacteria in city water supplies.
d) Odorous gases in ill-smelling water.
e) Ammonia in aqua ammonia.
f) The gas dissolved in the water from the well mentioned in the text, page 96.

5. Camphor crystals will not dissolve in water but will dissolve in alcohol.

6. Pupils may name some of these liquids (two are called for):

a) Turpentine for the oil in paint
b) Alcohol for iodine
c) Dry-cleaning liquid, such as carbon tetrachloride, for grease spots in clothing
d) Acetone for celluloid
e) Wood alcohol (methanol) for shellac
f) Kerosene for lubricating oil, bathtub "rings," etc.
g) Benzene for rubber

7. (*b*) Salt in ocean water. (c) Sweetness and color in molasses. (*d*) Coloring in fountain-pen ink.

If you do not know, you could find out by applying the three tests for the characteristics of a solution: (a) Are the particles invisible? Is the liquid clear? (*b*) Will the particles pass through a filter? (c) Do the particles remain scattered through the liquid?

If the answer to any one of these questions is "No," the liquid is not a true solution.

PROBLEMS TO SOLVE (P. 101). 1. Because kerosene will dissolve the grease so that it may be washed off with soap and water. Water will not dissolve grease.

2. The alcohol dissolves some of the varnish along the edges of the scratch. This varnish solution fills the scratch and stains the wood again.

3. The salt is dissolved in the water; that is, ocean water is a true solution of salt in water.

4. Pupils may list some of these solutions:

a) Vanilla extract and other extract flavorings.
b) Sugar in tea, coffee, etc.
c) Medicinal solutions, such as boric acid crystals in water, iodine in alcohol, and mercurochrome in water.
d) Varnishes.
e) Fountain-pen ink.
f) Household ammonia—a solution of ammonia gas in water.
g) Spirits of camphor—camphor crystals dissolved in alcohol.
h) Carbona, or carbon tetrachloride, to dissolve grease spots.

5. If the water being used in the boilers is perfectly clear, filtering it would not remove the minerals from it. They are in solution, and the particles are so small that they would pass through a filter.

6. By allowing the water to evaporate. As the water evaporates, the salt is left behind in solid, or crystalline, form.

PROBLEM 4 (OPTIONAL): HOW ARE MATERIALS PUT TOGETHER? (P. 102)

This problem introduces pupils to the molecular explanation of the behavior of matter. It is marked optional, but if the pupils are at all interested, the authors recommend that the problem be at least read and discussed. Many of the pupils will then be found to use the new ideas in their thinking, and the value of the ideas will constantly increase. The main ideas brought out are:

1. A theory is an apparently true, but not proved, explanation of facts; the molecular theory is used to explain many facts about matter.

2. Scientists believe (with good reason) that all kinds of materials (or matter) are made up of tiny particles, called molecules, that are unimaginably small and numerous.

3. Scientists also believe that there are spaces between the molecules of all substances but that these spaces are much larger in gases than in solids and liquids.

4. Molecules seem always to be moving.

5. When a solid dissolves in liquid, the molecules of the solid separate and go in between the molecules of the liquid; they can then go anywhere the liquid can go (but may not be able to evaporate).

6. Gases scatter to all space that is open to them because of the very rapid movements of their molecules.

7. The pressure of a gas in an inclosed space is due to the striking of the gas molecules against the sides of the inclosed space.

SELF-TESTING EXERCISES (P. 107). 1. Matter.

2. To explain what they notice happening.

3. A fact is something that has been proved to be true. A theory is an explanation that seems to be correct because it explains what we know happens, but it cannot be proved to be true.

4. The molecular theory is the theory that explains how matter acts on the basis that it is made up of tiny particles, called molecules.

5. The following are the explanations according to the molecular theory: (a) The coloring matter is broken up into its separate molecules, which spread between the molecules of water and color the entire glassful.

b) There are spaces between the molecules of gold, and the molecules of mercury can enter into these spaces.

c) Molecules of silver are moving and can move into the spaces between the molecules of brass.

d) The molecules of perfume can go to all parts of the room by moving between the molecules of air.

e) An air-pump can force air into a tire that already has much air in it because there are spaces between the molecules, and the molecules of air can be pushed closer together and so admit more air.

6. Because it seems to fit so many observed facts and to explain them.

PROBLEMS TO SOLVE (P. 107). 1. The particles that separate from the lump of sugar and go into the water are too tiny to see. No sugar is found on the filter paper because this mixture of sugar and water is a solution. The particles of sugar in the solution are separate molecules that are so small they pass through the filter paper with the water molecules.

2. Because the molecules of carbon dioxide are moving around rapidly among the molecules of the other gases in the air and are kept apart by these other molecules.

3. Molecules of sugar separate from the lump and go into the spaces between the molecules of coffee. Since molecules are always moving, they are finally scattered throughout the cup.

4. Molecules of the material of which moth balls are made separate from the balls and move in all directions among the molecules of air in the closet.

5. Molecules from cabbage move between air molecules to the butter and travel in between the molecules of butter.

6. The hydrogen molecules were moving and gradually passed out through the spaces between the molecules of rubber in the balloon.

7. The material of which the flower pot is made is porous; that is, there are spaces between the particles of the material, and the water molecules can pass through these small spaces.

8. Yes. The water is made of moving molecules that tend to bounce off from the cloth into the air. As those from the surface of the cloth leave it, other particles move up to take their places, and finally all of the water molecules have left the cloth and the cloth is dry.

Looking Back at Unit 3 (p. 108). Refer to the graph on page 82.

1. Take up space and have weight.

2. (a) A solid is a material that has a definite size and a shape of its own.

b) A liquid is a material that fills up a definite amount of space but has no shape of its own.

c) A gas is a material that has no definite size or shape.

3. The characteristics of a solution are:

a) The particles of the material dissolved in the liquid are too small to be seen even with a compound microscope.

b) The particles are so small that they pass through filter paper.

c) The particles stay all through the liquid and do not settle to the bottom or rise to the top even when the liquid has been allowed to stand for several days.

We use solutions in many ways in the home, in industries as important steps in the process of manufacturing things, in methods of obtaining some materials from the earth, etc.

4. (Optional) According to the molecular theory, or explanation of matter, molecules are the tiny particles of which all materials are made.

In a solid the molecules are moving and there are spaces between them, but the spaces are much smaller than in a gas or a liquid. The molecules of a solid are close enough together to give the material a definite shape.

In a liquid the molecules are moving, and they are farther apart than they are in a solid but not so far apart as they are in a gas. They are close enough together so that the liquid fills up a definite amount of space but does not have a definite shape.

In gases the molecules are bouncing very rapidly about and are much farther apart than in a solid or a liquid, so that the gas does not have any definite size or shape.

When a material dissolves, the molecules separate from the solid and move out into the spaces between the molecules of the liquid. The particles are small and move throughout the liquid with the result that the solid finally disappears.

ADDITIONAL EXERCISES (P. 109). 1. Fred forgot that all matter takes up space and that air is matter. He could have filled the bottle more quickly if the funnel had not fitted tightly into the neck of the bottle. This would have allowed the air in the bottle to move to some other space as the water came in through the funnel to replace the air in the bottle.

2. Other characteristics that all matter has are: (*a*) Matter can be changed in form but not destroyed. (*b*) All matter has the property of inertia; that is, all matter remains in the same place until moved by some force and then keeps on moving until some force stops it. (*c*) All matter is composed of elements.

3. The ammonia gas becomes dissolved in the water.

4. When the water is squeezed into the flask of ammonia from the medicine dropper, the ammonia gas dissolves in the water. This lessens the pressure of the air in the flask. The pressure of the air on the surface of the water in the beaker forces water up through the tube into the flask to replace the ammonia gas. The result is the fountain-like flow of water from the tube.

5. All materials have weight, but not all of them have the same relative weight. Hydrogen gas is lighter than air and is therefore

pushed upward by the heavier air around it. In a vacuum the hydrogen balloon would fall as rapidly as anything else.

6. The word *fluid* means a substance that can flow and can be either a liquid or a gas. The word *liquid* refers to the one form of matter that flows but has a definite volume.

7. Well water is likely to have minerals dissolved in it, while rain water is usually free from dissolved solids.

8. The sugar and water are occupying different parts of the same large space. The particles (molecules) of sugar are so small that they are located in the spaces between the molecules of water. Thus, actually, the molecules of water and the molecules of sugar are occupying different places within the same large space occupied by the solution as a whole.

9. Hot water will usually dissolve more material.

10. A dissolved solid raises the boiling point of water.

11. This experiment is easily carried out by lowering separate tubes filled with salt solution and with pure water into a mixture of snow or crushed ice and salt. Use plenty of salt. With thermometers take the temperatures of the liquids in the tubes when ice crystals begin to appear in them. Compare the temperatures.

The essential part of the experiment is taking the temperatures when ice begins to form in a solution and in pure water. Any available method of cooling may be used.

12. If this experiment is successful, a solution of carbon dioxide in water is prepared. The action between the citric acid of the lemon and the baking soda produces carbon dioxide in such quantities that its pressure causes much more to dissolve than would otherwise be the case. When the pressure is released, some of the dissolved gas forms bubbles in the liquid. If the taste is not unpleasant, the liquid may be drunk.

13. (a) The freezing point could be tested as in Additional Exercise 11. (This plan would be difficult if the liquid were some substance like alcohol, that has a very low freezing point.)

b) If the liquid were easily evaporated, it could be allowed to evaporate and leave any solids behind. This would not show gases that might be dissolved.

c) The odor would reveal the presence of some dissolved materials.

Tests for dissolved gases would be very hard for pupils to plan.

BULLETINS AND PAMPHLETS FOR UNIT 3

At the end of some units there is a list of bulletins and pamphlets that are available, either free or for a nominal sum. Most of these are publications of the United States government. Where prices are given, the bulletins may be obtained from the *Superintendent of Documents, United States Government Printing Office, Washington, D. C.* Where prices are not given, the bulletins may be obtained free by writing to the various departments, bureaus, or services at Washington, D. C., and specifying the exact title and number.

Great numbers of the publications of the United States government are of value to science teachers. Upon request the *Weekly Lists of Selected United States Government Publications* will be sent regularly. These describe many of the recent issues. A complete set of *Price Lists* of available publications may be obtained from the Superintendent of Documents.

Useful publications may also be secured free from the various state departments of agriculture and state universities and agricultural colleges.

Diamond Crystal Salt Company, Inc., St. Clair, Mich.
  Booklet on salt (free)
Farmers' Bulletin
  No. 1474. *Stain Removal from Fabrics, Home Methods.* 5c

VISUAL MATERIALS FOR UNIT 3

MOTION PICTURE

Eastman Classroom Films
  "Common Salt"

POSTERS

National Safety Council, 168 North Michigan Ave., Chicago, Ill.
  Free first-aid laboratory posters

UNIT 4

How Do Heating and Cooling Change Materials?

FUNCTION AND SCOPE OF UNIT 4. This unit attempts to acquaint pupils with basic understandings of the effects of heat upon matter. It deals with such common phenomena as expansion and contraction and changes of state as a result of heating and cooling and with the explanation of these phenomena in terms of the molecular theory. The latter material is optional and follows optional material in Unit 3. The main ideas of the unit are important, because they provide the pupils with material necessary for the interpretation of phenomena that are constantly taking place about them. Refer to graph, page 102.

For the best understanding of this unit pupils should be familiar with the main ideas of Problem 2 in Unit 3, "What Are Solids, Liquids, and Gases?" Optional Problem 4 of that unit can be very useful if the class has studied it.

The important ideas in the unit are supplemented in Unit 5 and are needed in the study of Unit 6.

In *Book 2* the ideas are used again, as follows: condition of materials in the sun and other heavenly bodies (Unit 1); effects of heat upon spring balance scales (Unit 2); heating and cooling in causing changes upon the earth's surface (Unit 3); convection currents in liquids and gases (Unit 4); heat as a form of energy (Unit 5); control of heat (Unit 6); temperature in relation to weather changes (Unit 7).

One of the important features of the unit is the provision of simple and interesting experiments by which pupils may discover for themselves the answers to the problems of the unit.

INTRODUCTORY EXERCISES (P. 112). 1. As the temperature changes, the liquid expands or contracts, with the result that it occupies more or less space, as the case may be.

2. The water disappears, or evaporates. Molecules of water at the surface pass off into the air. As these move away from the pan, more particles come from the water, until finally all the water has changed into a gas, or water vapor.

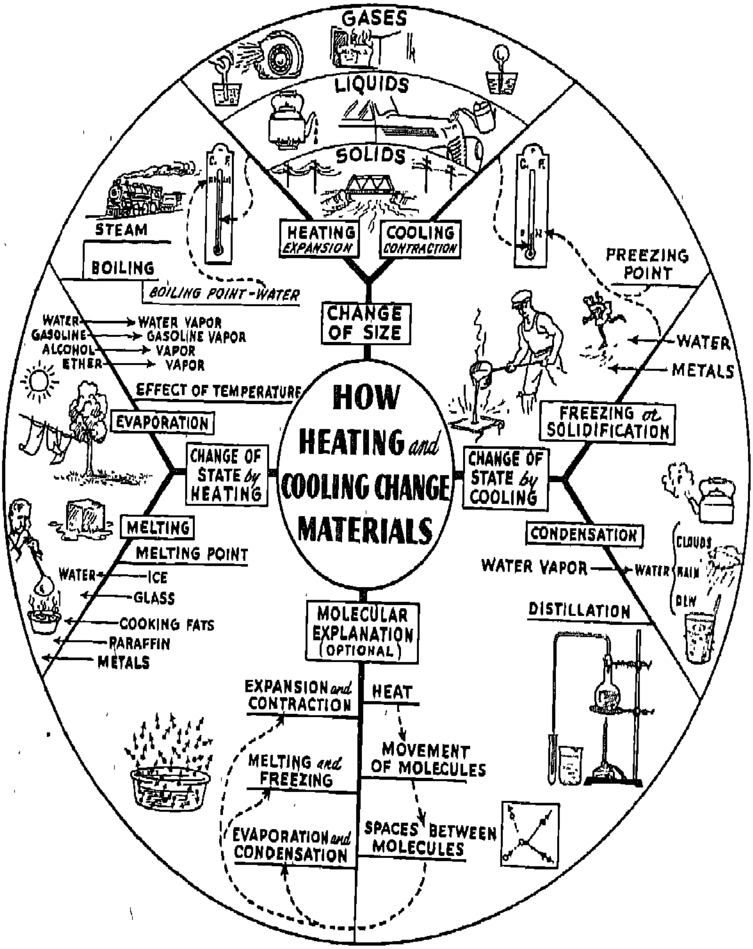

FIG. 6. GRAPH OF THE SUBJECT MATTER OF UNIT 4

3. The material of telephone wires contracts because of cold, and it becomes too short to cover the distance between poles. Since it is attached to two poles, it is broken by the pull of two poles on it.

4. Hot water expands glass, and the particles making up glass are pulled apart in some spot.

5. If the weather is very cold, look at the windows and see if they are "steaming up." If not, bring in a glass of very cold water and see if drops of water appear on the sides of the glass. If water appears, you will know that water vapor from the air has been condensed by the cold glass.

LOOKING AHEAD TO UNIT 4 (P. 113). Questions about common happenings that are familiar to pupils provide an introduction to the unit. Questions raised about these happenings should serve to arouse interest and to give an insight into the purpose of the unit as a whole. The answers to the questions are not attempted at this point; nor should the teacher provide them. Free discussion by the pupils of similar experiences should lead to a variety of questions that pupils would like to have answered. A list of such pupil-questions should be kept for reference as the study of the unit progresses.

PROBLEM 1: HOW DO HEATING AND COOLING CHANGE THE SIZE OF MATERIALS? (P. 115)

Expansion and contraction with changes of temperature are so common that every person should be in possession of the principle and use it in practical affairs as well as in the interpretation of situations to which it applies. In case it is found that the class is already able to apply the principle, Problem 1 may be used as a single reading assignment, after which the class may go on to the next problem. However, almost every class should discuss the scientific method and the meaning of a science principle as illustrated here.

It is the belief of the authors that use of the scientific method cannot be presented at the beginning of a course (as it was in Unit 1) and then function automatically throughout the course.

The method should be used in experimentation, in discussion, and whenever the opportunity presents itself.

Experiment 6 may be so presented by a committee of selected pupils or by the teacher as to help the pupils work out their own answer to the problem.

The idea of what a *principle of science* is fits naturally into the discussions that will follow the experimentation. The pupils should understand that under certain given conditions the same results can be expected in practically every case. Also, the idea of exceptions to some scientific principles should be developed, since the pupils will possibly raise questions involving such exceptions (i. e., expansion of water during cooling below 34° F.).

When the principles of this problem have been presented and are understood, there should be thorough discussion of, and effective practice in, using them to explain common happenings. The main ideas of the problem are:

1. Solids, liquids, and gases expand when heated.
2. Solids, liquids, and gases contract when cooled.
3. A principle of science is a statement that tells what happens under certain given conditions. There are some exceptions.
4. A principle of science may be used to explain many things that are happening every day.

EXPERIMENT 6. WHAT EFFECT DO HEATING AND COOLING HAVE UPON THE SIZE OF MATERIALS? (P. 115). The apparatus and materials for this experiment are:

Part a

Two ringstands (or other supports)
Two bricks (or other weights)
Thirty inches of wire, copper or iron, No. 30
Small weight
Bunsen burner

Part b

Test-tube
Water
Red ink
Stopper, 1-hole
Twelve inches glass tubing, small diameter
Piece of string
Support for test-tube
Bunsen burner

Part c

Apparatus used for part *b*
In addition:
beaker (or drinking glass)

a) The weight is lowered, showing that the wire becomes longer when it is heated.

As the wire cools, it shortens, pulling the weight back to its original position. Heating causes solids to expand, and cooling causes solids to contract.

b) As the liquid in the test-tube is heated, it expands and forces the liquid to rise in the glass tube.

Cold water causes the liquid in the tube to contract; thus the level of the liquid in the tube falls. Heating causes liquids to expand, and cooling causes liquids to contract.

c) When the test-tube is heated, air in the tube expands and occupies more space. Bubbles escape through the water in the beaker.

When the test-tube cools, the air in it contracts. Since the end of the glass tube is in the water in the beaker, water is forced to rise in the glass tube.

Heating of gases causes them to expand, and cooling causes gases to contract. Point out that air is a gas.

Self-Testing Exercises (p. 123). 1. (a) expand; (b) contract; (c) expand; (d) contract; (e) expand; (f) contract; (g) expand; (h) contract.

2. What happens under certain conditions.

3. By experimenting (and observing what happens whenever certain conditions occur).

Problems to Solve (p. 123). 1. A little slack, because they are hanging the wire between the poles while it is expanded. When the weather becomes cooler, the wire will contract.

2. Heat causes metal in cover to expand, so that it does not fit jar so tightly.

3. Liquid and fruit contract, and thus take up less space as they cool.

4. Yes. Tank will overflow, because the gasoline, cool when put in, will expand as sun heats it.

5. Concrete in pavement expanded. Probably insufficient room had been allowed for expansion; therefore pavement buckled and cracked.

6. Heat from sun expands ink and air in pen to the point where ink is forced out of the pen.

7. Softer. Warm air in the football will contract in the cold; thus pressure on the ball is less, so that it is no longer stretched so tightly as it was.

8. Air in the bottle expanded in the warmth of the room and began to escape from the bottle, making bubbles around the cap.

9. A thermometer could be made with the apparatus used for Experiment 6c, page 117 of the text. When temperature is high, heat expands the air, and the liquid is pushed down in the tube. When it is cold, the air contracts, and liquid rises in tube to fill space left when air molecules get closer together. In this type of thermometer the lower the liquid in the tube, the higher the temperature. A scale can be made and put behind the tube to show relative rising and falling of liquid. If the scale is numbered with 1 at the top, higher temperatures will be indicated by the higher numbers.

10. Some everyday happenings that might be explained by contraction and expansion are suggested. It is not likely that pupils will make up these particular exercises. (a) Why is an expansion tank necessary as part of a hot-water heating system?

b) A crack appeared where a built-in bath tub was fitted to the bathroom walls. Whenever the crack was patched with plaster, it opened up again. Explain why.

c) A clock with a pendulum seldom keeps good time both in summer and in winter. Why does it change?

d) A milk bottle exactly filled with cold water is weighed. The bottle and water are then heated quite hot and returned to the scales. The bottle of water is found to weigh less. Explain. (If this problem is presented to pupils, the explanation that "heat tends to rise" or "heat makes things lighter" should not be accepted. The water expands when heated, and some runs out of the bottle.)

e) A pipe that carries hot water to a bathroom always makes a queer "popping" sound when it has been allowed to become cool and then hot water is drawn through it. What could cause the sound?

f) A boy sealed both ends of a glass tube by heating them and allowing them to "run together." He continued to heat the tube. Suddenly a large bulge appeared where he was melting the glass. What caused it?

PROBLEM 2: WHAT EFFECT DOES HEATING HAVE UPON THE STATE OF MATTER? (P. 125)

This problem provides material for understanding the three forms of matter and the changes of matter from one state to another. A brief study of the different kinds of thermometers in common use and the important points at which changes of matter occur are introduced.

It should be noted that no attempt is made to have the pupils change Fahrenheit degrees into centigrade or centigrade into Fahrenheit. Such common knowledge as the freezing and boiling points of water in both Fahrenheit and centigrade degrees and the number of degrees between each of these points on both thermometers is all that should be expected of the pupils at this level.

The list of main ideas to be presented in this problem is lengthy. Therefore, even though most of the ideas are rather simple, enough time should be taken to make each of the ideas clear and at the same time show their relationship to each other. The main ideas are:

1. Solids may be changed to liquids by adding sufficient heat.

a) The temperature at which this happens varies with the kind of substance.

b) Some substances, such as water, have definite temperatures at which they melt and freeze.

c) Other substances do not have definite temperatures at which they melt and freeze.

2. Two kinds of thermometer scales are in common use.

a) Fahrenheit thermometers are in common use in homes and schools and for other purposes. Freezing point, 32°; boiling point, 212°.

b) Centigrade thermometers are generally used for scientific purposes. Freezing point, 0°; boiling point, 100°.

3. Liquids may be changed to gases by the addition of heat.

a) Liquids change to gases, or evaporate, at all temperatures.

b) Raising the temperature increases the speed of evaporation.

c) Different liquids evaporate at different rates.

4. If a liquid is heated enough, it will boil.

5. In an open dish a liquid cannot be heated any hotter than its boiling point.

EXPERIMENT 7. DOES HEATING MAKE WATER EVAPORATE MORE QUICKLY? (P. 129). The apparatus and materials needed are: Two dishes, glasses, or bottles of the same size; hot and cold water. *For supplementary suggestions:* Two handkerchiefs of the same size and material (in addition to the above apparatus). *For Figure 98, page 129, of the text:* test tube, support for test-tube, Bunsen Burner (or other source of heat).

The dish dipped into hot water dries more quickly than the dish dipped into cold water. The amount of time required for each of the dishes to dry might be clocked to make the conclusions more accurate.

Hanging a wet handkerchief of the same size and material in a cool place provides another convincing way of answering the question asked by the experiment. Also, the method used in Figure 98, page 129, of the text, can be used to verify the conclusions that have been reached: that heating speeds up the rate of evaporation and cooling slows down the rate of evaporation.

The experiment shown in Figure 100, page 132, may be used as supplementary material if time permits, or it may be used for individuals who work faster than the average pupil. The conclusion to be reached is that some liquids evaporate more rapidly than others.

The answer to the question under Figure 100, page 132, is that ether evaporates first, having the lowest boiling point, then, in order, gasoline and water. Oil evaporates so slowly as to be unnoticeable.

SELF-TESTING EXERCISES (P. 132). 1. *(a)* liquid, gas; *(b)* liquid, gas; (c) always; (*d*) at different rates; *(e)* some of the water runs off and some of it evaporates; *(f)* during the daytime; *(g)* the water on the surface evaporates; (*h*) true; *(i)* 212; *(j)* 100; (*k*) steam (gaseous water); (*l*) faster, same; (*m*) solid, liquid, gas.

2. By raising the temperature, or adding heat.

3. Some ways in which we use heat to make things are: *(a)*

To change solids to liquids in order to pour them into molds and in order to mix one kind of material with another to make new materials; (*b*) to soften materials, such as iron, copper, glass, etc., so that they can be pounded or bent into different shapes; (*c*) to change liquids to gases, as in making steam from water, and thus get power to run machinery.

PROBLEMS TO SOLVE (P. 133). 1. At high speed the water in the radiator is heated more. The hotter the water, the more quickly it evaporates, with the result that water must be added oftener on a long, fast drive.

2. Moisture evaporates and leaves the solid materials.

May be prevented by keeping candy in air-tight jar or box:

3. If exposed to air, moisture will evaporate from the paste and leave the solid parts. These will be crumbly and will not spread and stick.

4. Probably pop-corn "pops" because heat of fire changes the water in the kernels to a gas, steam. Gas expands because of further heat until the pressure of the gas is so great that it bursts the kernel.

5. So that water is boiling steadily but not violently.

Since temperature of boiling water is always the same, regardless of speed, it is a waste of fuel to turn gas up to boil water more rapidly.

6. No. Chocolate does not change suddenly and quickly to liquid, but gets softer and softer gradually, as butter does.

Reasons should probably be pupils' own observations.

7. Asphalt starts to melt on very hot days and becomes soft enough for an impression to be made in it by heels. It melts gradually and has different degrees of softness.

8. Because ice has a definite melting point. As long as it is a solid, it is brittle and cannot be shaped by hammering. In the case of iron or copper, heat softens them slowly, and they can be shaped when they reach the right degree of softness.

9. We would not be able to spread it in soft consistency as we do now. Below the melting point it would be too hard, and above the melting point it would be a liquid. We could not serve it in the form we do now unless temperature were well below the melting point.

PROBLEM 3: WHAT HAPPENS TO MATERIALS WHEN THEY ARE COOLED? (P. 134)

This problem presents the effects of cooling upon gases and liquids. Its relationship to Problem 2 must be clearly understood, since evaporation must take place before condensation can occur. In many cases teachers present evaporation and condensation as a single topic. However, from their own experiences the authors feel that at this level it is best to present the topics separately and in the order stated. The purpose of this method of presentation is to avoid confusion, since these two main ideas involve the understanding and use of many smaller, related ideas.

Since pupils will possibly have had previous experiences with the phenomena of evaporation, the prediction idea at the first of the problem may well be used before the experiments proceed. Have it thoroughly understood that predictions of outcomes, both by pupils and scientists, are not mere guesses. They must be based upon previous experiences and upon careful reasoning.

These experiments always create a great deal of interest on the part of pupils and should be done by pupils working in small groups or as pupil demonstrations.

Caution should be given here to have pupils get the idea that steam is invisible. The use of the word *cloud* may be substituted for *steam* in reference to the condensed water vapor that is popularly called *steam*.

Pupils should readily understand at the conclusion of the problem: "In Problem 2 we changed the state of matter by heating it. Now we are changing the state of matter back to its original form by cooling it."

The list of main ideas to be presented is again rather lengthy, and, as with Problem 2, sufficient teaching time should be given for the clear understanding of these ideas. The main ideas of the problem are:

1. Gases may be changed to liquids when they are sufficiently cooled.

a) The temperature varies with the kind of substance.
b) When water is changed to steam, the solid materials dissolved in the water do not change into gases. The condensed liquid is then free from the solids.
c) Hot air can hold more water vapor than cold air.
d) When water vapor comes out of the air, it condenses into liquid water.
e) If air has a large amount of water vapor in it, it needs to be cooled only a few degrees to cause condensation.
f) If air has a small amount of water vapor in it, it must be cooled many degrees to cause condensation.

2. Liquids can be changed to solids when they are sufficiently cooled.
a) Every liquid can be changed to a solid if it is cooled enough.
b) Liquid water changes to ice at 32° F. or 0° C.
c) Some substances have no definite temperatures at which they change to solids.

EXPERIMENT 8. WHAT HAPPENS TO STEAM WHEN IT IS COOLED? (P. 135). The apparatus and materials needed are:

Ringstand with ring
Piece of wire gauze to be placed beneath flask
Flask
Clamp to support flask
Stopper, 1-hole
Bunsen burner
Glass delivery tube, 24-inch length, to fit hole in stopper
Test-tube
Beaker (or glass)
Water, cold

Figure 101, page 134, shows a simple apparatus set-up for the experiment. If you use the Study-Book for Science Problems 1, have pupils refer to page 61 for help in bending the glass tubing.

The steam cannot be seen in the flask or in the delivery tube. Only a small amount of steam changes to liquid when the test-tube is not placed in cold water. (Where a visible cloud of "steam" appears outside the delivery tube, the steam has condensed into tiny droplets of liquid water in the air. These soon evaporate again.)

When the test-tube is placed in cold water and steam is passed into the test-tube, all the steam changes into a liquid.

EXPERIMENT 9. WHAT HAPPENS WHEN WATER IS DISTILLED? (P. 136). The apparatus and materials are: Same as for Experiment 8, with some common table salt in addition.

Dissolve some salt in the water in the flask. Let the pupils taste the water to see that it is salty. The distilled water does not taste salty. Solid materials dissolved in the water do not change into gases.

EXPERIMENT 10. HOW CAN WATER VAPOR FROM THE AIR BE CONDENSED? (P. 138). The apparatus and materials are: Bright tin cup, cold water, salt, crushed ice.

If the tin cup is cool, moisture may form on the outside of the cup when cold water is put into it. If moisture does not condense at once, add crushed ice and salt. The air has water vapor in it. Contact with the side of the cup chills the air so that it can hold less water vapor. Moisture in the air then condenses.

SELF-TESTING EXERCISES (P. 139). (*a*) gas; (*b*) cooled; (*c*) tiny drops of liquid water; (*d*) less; (*e*) cooled; (*f*) less; (*g*) cooled; (*h*) different.

PROBLEMS TO SOLVE (P. 140). 1. When water evaporates from the ocean, dissolved salt is left in the ocean. Rain that falls is thus salt-free ocean water that has condensed. Rain water is mostly distilled ocean water.

2. Warm air in the room is cooled when it strikes the cold glass; therefore it cannot hold so much water vapor. Vapor condenses on the cold glass.

3. Warm air expelled from the lungs contains much water vapor. When it mixes with air much colder than our bodies, the water vapor condenses and forms liquid droplets in the "clouds" we see.

4. Water vapor in air condenses to liquid water when brought into contact with a cold pitcher.

5. No. Try the experiment, adding some soil to the flask to make muddy water.

This might be very useful information in case one needs water when the only available source has a great deal of mud or other materials dissolved or suspended in it.

6. Several examples are suggested: (a) Paraffin is melted so that it can be poured over jelly and other preserves to keep them.

b) Solder is melted for use in putting metals together or in patching holes in metal.

c) Lard and similar substances are melted when they are to be used for frying and similar methods of cooking.

d) Chocolate is melted to make cake, icing, and candy.

e) In polar regions ice or snow must be melted to drink and use in other ways.

f) Zinc is melted to "galvanize" pails, fences, etc.

g) Sealing wax is melted when it is to be used.

h) Lead is melted to pour into joints in plumbing systems.

i) Pitch is melted for coating roofs and for other construction purposes.

7. Several examples are suggested: (a) Glass in electric-light bulbs, dishes, window-panes, etc.

b) Iron skillets, radiators, etc.

c) Toy soldiers.

d) Bronze statuary.

e) Grills and other ornaments on automobiles.

f) Many articles made from plastics: measuring spoons, camera parts, etc.

g) Articles that are welded by electricity, oxyacetylene torches, arcs, spot welding, etc.

PROBLEM 4 (OPTIONAL): HOW CAN WE EXPLAIN HOW HEAT AFFECTS MATTER? (P. 141)

Have a review discussion of Problem 4, Unit 3, for the purpose of recalling what pupils have learned about the molecular theory. The first part of this problem explains in terms of the molecular theory (1) why materials expand when they are cooled and (2) the changes of states of matter. The second part of the problem explains, also in terms of the molecular theory, what causes evaporation.

Constant reference to the principles of the first three problems of this unit should be made for recalling the principles presented there. Have the pupils make a list of these principles and then explain them in terms of the molecular theory. An example is given:

Scientific Principle	*Explanation*
Materials expand when they are heated.	Molecules move faster when they are heated. Molecules bump into each other and knock each other farther apart. When this happens, materials expand.

Special attention will need to be given to explaining, in terms of the molecular theory, how boiling takes place, since this phenomenon is slightly more difficult to explain than others in this problem.

This problem is optional, but, as with Problem 4, Unit 3, it is urged that the problem be included as a regular part of the unit in all cases where time will allow for it. A list of the main ideas of this problem follows:

1. When a material is heated, its molecules move faster.
2. Materials expand when heated because the molecules collide harder and are forced farther apart.
3. When a material is cooled, its molecules move more slowly.
4. Materials contract when cooled because the molecules collide with less force and get closer together.
5. A solid melts when heated because its molecules are knocked loose from each other and can move around more freely.
6. A liquid evaporates more rapidly when heated because, due to their more rapid motion, its molecules knock each other apart more rapidly.
7. When a gas is cooled, its molecules move closer together, and the gas changes to a liquid.

8. When a liquid is cooled, its molecules become more closely attached together, and the liquid changes to a solid.

9. When the temperature of water reaches the boiling point, collisions of some of the molecules force them so far apart that they form bubbles of steam; increased heating causes more bubbles to form without raising the temperature.

SELF-TESTING EXERCISES (P. 144). (a) farther apart; (b) farther apart; (c) closer together, liquid; (d) escapes; (e) bubble of steam; (f) gas.

PROBLEMS TO SOLVE (P. 145). 1. To show any difference, the bottle must be open.

2. In the warmer place the molecules of water in wet clothes move faster and knock each other off the clothes faster.

3. Cooling vapor a sufficient amount causes some of it to condense. Cooling (removing heat) makes the molecules slow down and come closer together. Finally they come so close together that they become a liquid.

4. No. In cooler water the molecules are able to stay closer together. Thus more of them can be put into a quart container. (*Alternate answer:* In warmer water the molecules are farther apart, and fewer can be put into a quart container.)

LOOKING BACK TO UNIT 4 (P. 145). The graph on page 102 may be used to help in the organization of the unit.

1. The text at this point may lead to some confusion. Not all big ideas of science are principles. In the following list the principles are marked with asterisks.

*a) Solids, liquids, and gases expand when heated and contract when cooled. (Pupils may divide this into three principles.)
*b) Solids change to liquids when heated hot enough.
*c) Liquids change to gases, or evaporate, when heated hot enough.
*d) Heating increases the speed of evaporation.
*e) Liquids evaporate at different rates.
*f) Gases change to liquids when they are cooled.
*g) Liquids change to solids when they are cooled.
h) The molecules of a material move faster when they are heated.

2. Pupils' statements of meaning will need to be read and cor-

rected individually, as they will vary widely in phrasing. These exercises may be prevented from becoming pure copy work by proper management on the part of the teacher. In some classes no difficulty in attitude will be encountered. In others the teacher may need to show the pupils that, if their study of the unit has been thoroughly done, they can state the meaning of each important word in some way. It may, at times, be necessary to give the whole class the vocabulary exercise at one time as a written "test." The meanings may then be discussed after pupils have exchanged papers. Many pupils will need instruction in writing clear statements of meaning. This instruction should be provided wherever need for it becomes evident.

The *boiling point* of a liquid is the temperature at which bubbles of gas form inside it.

Centigrade is the name of a kind of thermometer scale that has 100 degrees between the freezing and boiling points; 0° is the freezing point, and 100° the boiling point.

To *condense* means to change from gas to liquid.

To *contract* means to grow smaller.

Distillation is the process of changing a liquid to a gas by heating it and then changing it back to a liquid by cooling it. The liquid can often be freed from dissolved solids in this way.

To *evaporate* means to change from liquid to gas.

To *expand* means to grow larger.

A *thermometer* is an instrument used to measure the temperature—how hot or cold a substance is.

The *freezing point* is the temperature at which a liquid freezes, or changes from a liquid to a solid.

Fahrenheit is the name of the kind of thermometer scale on which the boiling point is at 212° and the freezing point is at 32°.

ADDITIONAL EXERCISES (P. 145). 1. So that when they cool and contract, they will pull and hold the pieces of steel tightly together.

2. Heat of the sun changes droplets of water in the cloud into invisible water vapor, or evaporates the water in the fog.

4. Water will not evaporate so quickly after the sun has gone down; therefore more of it will be available to the plants.

5. The main differences are: (1) The degree marks are farther apart, and fractions of degrees are usually marked. (2) There is a

narrow place in the tube of the thermometer so that the mercury does not go back down in the tube until it is shaken down.

6. The type of metal thermometer commonly seen on oven doors is made of two flat strips of brass and iron, fastened together tightly and curved. The brass strip, which expands more than iron, is usually on the inside of the curve. When the temperature increases, this bar bends outward and turns the pointer. When the temperature drops, the bar turns in.

Principle: Solids expand when heated and contract when cooled.

7. Pupil activity. The bar made of iron and brass together will bend with the brass on the outside or longer side of the arc.

When the double bar is heated, the brass expands faster than the iron and pushes around the iron, forming a curve.

8. The thermostat consists of a strip of iron and a strip of brass fastened together along their length, as in exercise 7. As explained in exercise 7, the end of the bar bends back and forth with changes of temperature. The back-and-forth movement of the bar is transmitted to a pointer that makes or breaks contact in the electrical circuit that starts or stops the heating system.

9. A recording thermometer uses a coil made of strips of two metals, such as iron and brass, that expand unequally. One end of the long spiral is fastened, and the other end is free and has a pointer attached to it. As the temperature changes, the metals expand and contract unequally, causing the spiral to coil more or less tightly. The motion of this is transferred to the pointer, which has a pen attached to it. A piece of paper is attached to the instrument and rotated by clockwork. The pen moves up and down on the moving paper as the coil expands or contracts and records the changes in the temperature.

10. Interesting temperatures for the wall chart.

a) Boiling point of water: 100° C., 212° F.
b) Freezing point of water: 0° C., 32° F.
c) Melting point of iron: pure iron, 1505° C., 2741° F.; pig iron, 1130° C., 2066° F.
d) Melting point of gold: 1063° C., 1945° F.
e) Oxyhydrogen blowpipe: 2844° C., 5151° F.
f) Temperature of human body: 37° C., 98.6° F.
g) Boiling point of alcohol: 78° C., 172° F.

BULLETINS AND PAMPHLETS FOR UNIT 4

Agricultural Bulletin
    No. 532. *Expansion and Contraction of Concrete and Concrete Roads.* 10c
Standards Circular
    No. 8. *Testing of Thermometers.* 10c
Taylor Instrument Company, 95 Ames St., Rochester, N. Y.
    Free pamphlets on various scientific instruments

VISUAL MATERIALS FOR UNIT 4

MOTION PICTURES

Ball Brothers Company, Muncie, Ind.
    "The Romance of Glass" (free)
General Electric Company, Visual Instruction Section, River Road, Schenectady, N. Y.
    "Liquid Air" (rent or free)
U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.
    "Heat Treatment of Steel"
    "Story of Lead Smelting"
    "The Story of Steel"
    "The Metals of a Motor Car" (All are free.)

UNIT 5

How Can One Kind of Substance Change into Another Kind?

FUNCTION AND SCOPE OF UNIT 5. This is one of the series of units that present science concepts basic to a large number of environmental units. An understanding of the nature of chemical change is essential to the understandings presented in Units 6, 8, 9, and 10 of this book. Each of these units applies to everyday situations the ideas presented in this unit.

Careful study of the unit graph will clarify the objectives of the unit.

INTRODUCTORY EXERCISES (P. 148). 4. Some new products that might be mentioned are: (a) Cellophane.

b) A rayon yarn, called acele, made by Du Pont.

c) Lucite, a clear plastic used in making handles for brushes, pipe stems, etc.

d) Various other plastics: cel-o-glass, a "plasticoated" wire mesh used to make lightweight doors in air-conditioned buildings.

e) Pipes for men made in bright colors of "plastacele."

f) Freon, a new refrigerating gas that is nontoxic, nonexplosive, noninflammable, and noncorrosive.

g) New metal: New lightweight metal alloys used in airplanes and streamlined trains. Many of the rare metals are now being used as methods of obtaining them and preparing them improve.

6. Because it prevents oxygen from coming in contact with the iron.

7. *Element:* iron, copper.

Compound: salt (sodium chloride, $NaCl$), water (H_2O), sulphuric acid (H_2SO_4).

Mixture: air, a mixture of several gases (oxygen, nitrogen, carbon dioxide, water vapor, and some others); soil, a mixture of many different compounds and elements; milk.

LOOKING AHEAD TO UNIT 5 (P. 149). After the pupils have read this section, questions should be asked to bring out the following points: (1) Science enables us to do things and to

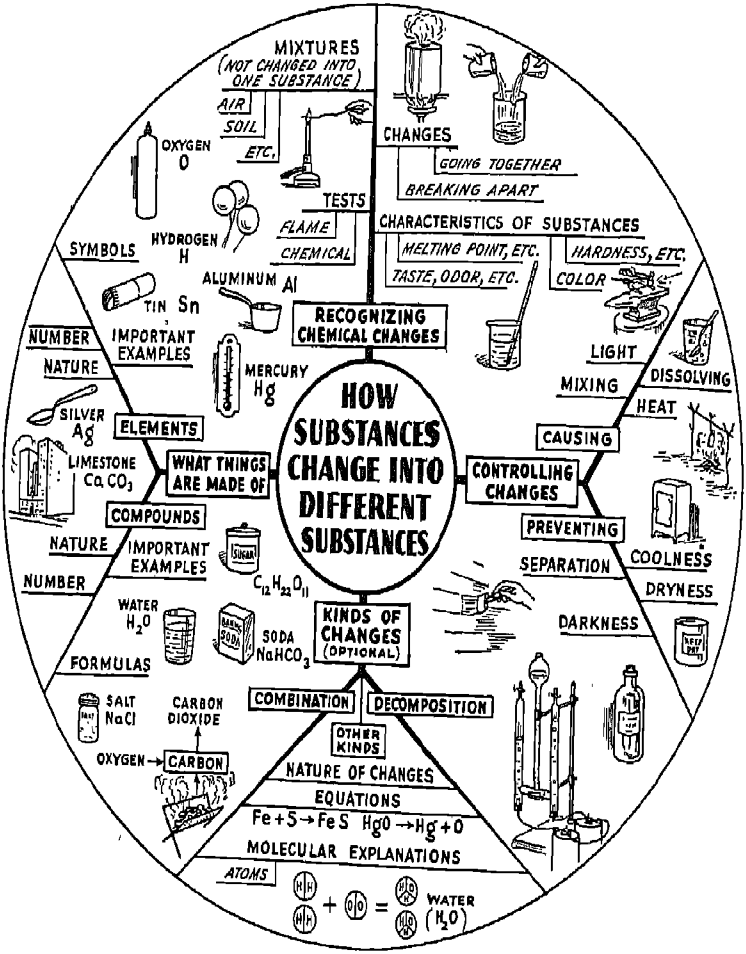

FIG. 7. GRAPH OF THE SUBJECT MATTER OF UNIT 5

explain things that appear as magic to those who do not understand them. (2) When the physical state of a material is changed (water to liquid), the material does not change into a new material. (3) In chemical changes the material changes into a new material. (4) Some chemical changes are helpful; others are harmful. (5) In order to control chemical changes, scientists need to find out what goes on during such changes. Study of the problems of the unit will then clarify the meaning of the last three points and bring out their applications.

PROBLEM 1: WHAT ARE MATERIALS MADE OF? (P. 151)

This problem presents an elementary notion of the nature of elements and compounds. The meanings of symbols and formulas are carried to a higher level in Problem 4. Following are the main ideas presented in the problem:

1. There are a great number of different kinds of materials.

2. Materials that cannot be separated into simpler materials are called elements.

3. Materials that contain two or more simpler materials (elements) are called compounds.

4. We cannot tell by looking at it whether a material is an element or a compound.

5. All of the materials in the world are made of 92 elements. Some common materials are elements, and some are compounds.

6. Chemists use a symbol to stand for an element.

7. Different elements have different physical properties and are used for different purposes.

8. Chemists use a formula to stand for a compound.
a) A formula is made up of symbols that tell which elements make up that compound.
b) The number after each symbol in a formula tells the chemist how much of that element unites with other elements to form the compound.

EXPERIMENT 11. WHAT HAPPENS WHEN MERCURIC OXIDE IS HEATED? (P. 152). The apparatus and materials called for are:

Ringstand
Clamp, burette
Test-tube, Pyrex or hard glass

Mercuric-oxide powder
Paper for plug
Bunsen burner
Thin pine splinter

Note that a glowing, not a flaming, splinter should be used. A thin splinter, preferably of soft pine, gives far better results than a match. (Matches are chemically treated to prevent glowing after the flame is extinguished.)

Be sure to heat the red rust of mercury until all of the red powder disappears. Mercury can be seen as a mirror-like coating or as silvery drops on the inside of the test-tube.

SUPPLEMENTARY EXPERIMENT FOR EXPERIMENT 11 (P. 152). The apparatus and materials needed for this are:

Ringstand
Clamp, burette
Four grams potassium chlorate
Two grams manganese dioxide
Test-tube, Pyrex or hard glass
Rubber stopper
Glass tubing

Rubber tubing
Bunsen burner
Pan, wide and deep
Three or four bottles, wide-mouthed, for collecting gas
Glass plates to cover bottles
Water

If oxygen is desired in large quantities to demonstrate the properties of the element, a mixture of potassium chlorate ($KClO_3$) and manganese dioxide (MnO_2) should be used. Pulverize about four grams of potassium chlorate, and mix it on paper with two grams of manganese dioxide. Place the mixture in a Pyrex or hard glass test-tube provided with a stopper and glass tubing. Slip a piece of rubber tubing over the end of the glass tubing and arrange as shown in Figure 8. Obtain several wide-mouthed bottles and a glass plate to cover each. Fill the bottles with water and invert in the pan so that the water remains in the bottles. Heat the mixture in the test-tube and collect the gas in the bottles. When the bottles are filled, slip a glass plate under the mouth of each, remove them from the water, and set them, mouth upward, on a table.

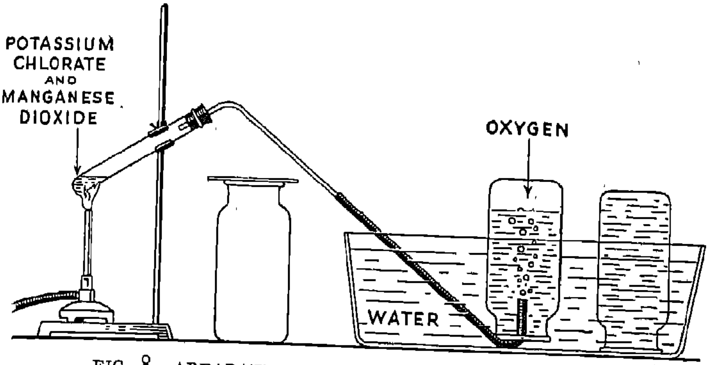

FIG. 8. APPARATUS FOR PREPARATION OF OXYGEN

Several interesting experiments may be performed: (a) A lighted candle lowered into a bottle will burn brilliantly.

b) If the end of a piece of picture wire is unbraided and dipped into sulphur, and the sulphur is ignited and lowered into a bottle of oxygen, the wire will burn, giving off many sparks.

c) Other interesting experiments may be found in chemistry textbooks and in popular science books.

Self-Testing Exercises (p. 159). 1. A material that contains two or more simpler materials.

2. An element cannot be separated into simpler materials, because it is made of only one kind of material. A compound can be separated, because it is composed of more than one kind of material.

3. No. Responses are individual, but the text provides data on mercuric oxide, water, sugar, and salt. Water, for example, is made up of hydrogen and oxygen, which are gases at ordinary temperature. From looking at water one would not know that it is made up of hydrogen and oxygen.

4. All materials are elements or are made up of elements put together in various ways. There are only 92 elements, but all the thousands of different materials are made from these elements.

PROBLEMS TO SOLVE (P. 159). 2. Baking soda ($NaHCO_3$), Chile saltpeter ($NaNO_3$), lye ($NaOH$), table salt ($NaCl$), washing soda (Na_2CO_3).

All five contain the one element, sodium, but each has sodium combined with a different element or elements. From this we see the possibility of the number of combinations of different kinds that can be made from different elements.

3. That it cannot be separated into any simpler materials, but can probably be combined with other elements to form compounds.

4. That it is made up of more than one element and thus can be broken up into other substances.

PROBLEM 2: HOW CAN WE RECOGNIZE A CHEMICAL CHANGE? (P. 159)

This problem presents an elementary notion of the nature of chemical change. The concept that a chemical change results in a new material is developed by experiments in which the characteristics of materials before and after a chemical change are compared. The main ideas of the problem are:

1. We recognize things by their characteristics; we may discover these characteristics by looking, lifting, smelling, touching, tasting.

2. Chemists determine what materials are by using special tests. In a chemical test for a material a certain change takes place when that material is present and certain things are done. This exact change does not take place if that material is not present.

3. In a chemical change the material always changes to a different material.

a) This change is shown by a change in the characteristics of the material.

b) One material may change into a different material or several materials.

c) Two materials may be changed into one material. When two materials go together to form a new material, we say that the materials combine.

4. Most of the materials around us are mixtures of elements and compounds.

5. A pure material contains only one element or one compound.

Experiment 12. How Do Chemists Make Tests to Tell What a Substance Is? (p. 160). The apparatus and materials for this experiment are:

Part a

Wire, small iron, 10-12 inches long
Pliers, wire-cutting
Hydrochloric acid, dilute and strong
Bunsen burner
Table salt
Glass plates
Potassium nitrate (or any potassium salt)
Calcium chloride (or any calcium salt)
Copper sulphate (or any copper salt)

Part b

Starch, laundry
Iodine, dilute solution
Potato
Knife, for cutting and peeling potato

a) Better results will be secured with all materials except copper compounds if a piece of platinum wire fused in a glass rod is used. The high-school chemistry laboratory usually has this. If iron wire is used, best results are obtained by cutting off the used loop and forming a new one each time a different compound is used.

The sodium salt will give a yellow flame; the potassium salt, a purplish-lavender flame; the calcium salt, a reddish flame; and the copper salt, a greenish-blue flame. (Caution: Do not use copper with a platinum wire.)

b) Tincture of iodine, obtainable at any drug store, may be used. The results will be more satisfactory if the iodine solution is diluted to a very light brown color. Starch in the presence of iodine turns blue or blue-black.

Self-Testing Exercises (p. 161). 1. *Glass:* solid, smooth, easily broken, can be melted gradually, will not burn or dissolve, lets light through.

Rubber: elastic, flexible, waterproof.
Silver: metal, silver color, can be hammered into various shapes.
Cork: very light, floats, porous, easily cut.

2. By making many different kinds of measurements and tests. If he finds that a material always behaves in the same way under a certain set of conditions and that other substances do not behave in this way, he has a test for the substance.

3. No. Because the chemist would not know whether the material he was testing really did not contain the substance he was testing for or whether the test had just failed to work and thus had not shown the presence of the substance.

EXPERIMENT 13. WHAT HAPPENS WHEN WOOD IS HEATED? (P. 162). The apparatus and materials are:

Ringstand	Glass tubing, 3 inches long
Clamp	Wood, 2 inches long, small enough to fit test-tube
Test-tube	Bunsen burner
Cork to fit test-tube	

This experiment presents no special difficulties if the usual apparatus is present. In case glassware and a gas burner are not available, some pupil can carry out the experiment at home by putting pieces of wood in a baking-powder, or similar metal, can with a reasonably tight lid. A small hole should be punched through the lid to allow the gases to escape. The can with the wood in it may be heated over a gas stove (in which case care should be taken to burn the escaping gases), or it may be set over the glowing coals in a wood or coal cookstove or furnace until gases cease coming out of the can. Cool the can before opening it.

EXPERIMENT 14. WHAT HAPPENS WHEN SULPHUR AND IRON ARE HEATED TOGETHER? (P. 163). The apparatus and materials are:

Ringstand	Bunsen burner
Clamp	Iron powder, one-third test-tube
Five test-tubes	Powdered sulphur, one-third test-tube
Small dish	Water

a) Another method of demonstrating that the iron and sulphur may be easily separated is to pour the mixture on a paper and then pick out the iron with a magnet.

b) Complete chemical combination of all the iron and sulphur may not take place, but enough combination will take place to illustrate that a chemical change has occurred.

SUPPLEMENTARY EXPERIMENT FOR EXPERIMENT 14*a* (P. 163). The apparatus and materials needed are: long glass tube that is an inch or more in diameter, soil, and water.

Another method of demonstrating the nature of a mixture is to obtain some ordinary soil and a long glass tube. Partly fill the tube with water and then pour in six or eight inches of soil. Shake the tube until the soil is thoroughly mixed with water and then allow it to stand for several hours. The soil will arrange itself in the bottom of the tube according to the size and density of the particles.

SUPPLEMENTARY DEMONSTRATION EXPERIMENTS FOR EXPERIMENT 14*b* (P. 163). 1. The apparatus and materials needed are: potassium permanganate, glycerine, mortar and pestle, metal plate, medicine dropper.

A very striking example of a chemical change can be demonstrated with the aid of potassium permanganate and glycerine. Powder the potassium permanganate and arrange it in a tiny pile on a piece of metal. Make a little hole in the top of the pile and add a drop or two of glycerine. A chemical combination will take place, and the material will burst into flame.

2. The apparatus and materials needed are:

Sugar
Potassium of chlorate
Graduated cylinder
Mortar and pestle
Wooden splint
Metal plate
Sulphuric acid
Glass tube

Another interesting experiment *for the teacher to do* is to mix equal volumes of very finely powdered sugar and finely powdered potassium of chlorate. **Powder the two materials**

separately, because an explosion may take place if they are powdered together. Mix the two materials with a **wooden** splint. Place the mixture on a metal plate and add a drop of concentrated sulphuric acid.

The best way to handle the sulphuric acid is this: Obtain a glass tube about one foot long, preferably with the end drawn out like a medicine dropper. Insert the lower end into a bottle of concentrated sulphuric acid, so that the liquid will rise about one-quarter of an inch in the tube. Place a finger over the top of the tube and withdraw the tube from the bottle. If the finger is removed from the top of the tube, the liquid will run out. This is a safe method of handling the acid, because the action is sometimes so violent that it may scatter particles of sulphuric acid on a hand held too close.

SELF-TESTING EXERCISES (P. 165). 1. When a new material with characteristics different from the original materials has been formed.

2. Pupils should be required to state some of the characteristics that are different.

The wood was light-colored, solid, tough, and would burn with a yellow flame. The material (charcoal) that is left is brittle, black, and burns with a glow or with a small blue flame. There were also gaseous materials, although only a solid had been put in.

Iron was silvery gray, relatively heavy, magnetic; sulphur was yellow, relatively light, non-magnetic. The new material is black, brittle, non-magnetic.

Mercuric oxide was a red powder; it changed into a colorless gas and a silvery liquid.

Thus in each case the original material changed into one or more new materials with different characteristics.

[illegible] Because the materials at the end of the various processes do [illegible] have [illegible] characteristics of the original materials but have characteristics [illegible] their own. For example, the cake is very different [illegible] the materials that entered into making it.

[illegible] Responses will vary, but pupils may mention some of these [illegible] [illegible] Chemical changes going on inside our bodies—di[illegible] [illegible] food, etc.

b) Gasoline in automobiles being changed chemically as it burns. The materials coming from the exhaust pipe are one evidence.
c) Iron in water pipes, fences, etc., rusts. The reddish material found is different from the iron and oxygen from which it is made.
d) Silver tarnishes. Black substance on the silver is formed from some of the silver and hydrogen sulphide from gas and coal. The black substance is different from silver and from hydrogen sulphide.
e) When you burn a piece of toast, you change the materials in the flour to carbon that is black and has quite different characteristics from the flour or the bread made from the flour.

Self-Testing Exercises (p. 167). 1. Many mixtures.

2. A material that contains one element or one compound only.

3. A mixture. You can still see the sugar and sand as separate substances. No change has occurred to make either of them into a new material with characteristics of its own.

4. Usually mixtures. The dissolved substance still tastes as it did before. If colored, it keeps its color. By evaporating the water, it can usually be obtained again unchanged.

5. Because it contains many different compounds and elements all mixed together.

Problems to Solve (p. 167). 1. Pupils may answer by writing C after the chemical changes and 0 (zero) after the other changes.

a) No
b) Yes
c) No
d) No
e) Yes
f) Yes
g) No
h) Yes
i) No
j) Yes
k) Yes
l) No
m) No
n) Yes
o) Yes
p) Yes

2. By the uniting of the oxygen and hydrogen, a new material, water, is formed that has characteristics of its own. The oxygen in the water is no longer free to behave with its own characteristic—that of oxidizing.

3. Because iron and oxygen united to form a new material that does not have the magnetic properties of iron.

4. No. The sugar is just dissolved in the tea. We know it is still sugar because we can taste its sweetness. If the tea is heated until all of the water evaporates, the sugar will be left.

5. Yes. Because materials were formed that had different characteristics from the original materials.

PROBLEM 3: HOW CAN WE CONTROL CHEMICAL CHANGES? (P. 169)

The use of various chemicals in the home is quite common. One purpose of this problem is to show the reasons underlying the suggestions given on containers for the storage of chemicals. Another purpose of the problem is to show how various methods may be used to increase the speed of chemical changes. Following are the main ideas of the problem:

1. Some ways of causing chemical changes to take place are: (*a*) by heating materials, (*b*) by dissolving the substances entering into the change, and (*c*) by exposing materials to light.
2. Chemical changes may be stopped or slowed down (*a*) by keeping materials that will combine apart, (*b*) by keeping materials in a dark place, (*c*) by keeping materials cool, and (*d*) by keeping materials dry.

EXPERIMENT 15. CAN WE BRING ABOUT CHEMICAL CHANGES BY DISSOLVING SUBSTANCES? (P. 171). The apparatus and materials are: one-half teaspoon citric-acid crystals, one-half teaspoon baking soda, test-tube, water.

No difficulty will be experienced with this experiment.

EXPERIMENT 16. ARE CHEMICAL CHANGES BROUGHT ABOUT BY LIGHT? (P. 171). The apparatus and materials are: silver nitrate, water, two test-tubes.

Films are made of a thin strip of transparent plastic. This strip is then coated with a very thin layer of gelatin, which contains a finely divided cream-colored solid, called silver bromide. The following supplementary experiment shows what happens.

SUPPLEMENTARY EXPERIMENT FOR EXPERIMENT 16 (P. 171). The apparatus and materials needed are:

Graduate cylinder
Potassium bromide
Water
Silver nitrate
Filter paper (or cloth)
Two test-tubes

Make a solution of a few crystals of potassium bromide in ten cubic centimeters of water. To this add a few cubic centimeters of a solution of silver nitrate. Note the creamy appearance of the solid formed when the two solutions are mixed. This creamy substance is silver bromide. Pour the liquid through a filter paper or cloth and catch the silver bromide. Expose it to direct sunlight for a few minutes and observe what happens.

The bromide is yellowish, and upon exposure to light first appears green, then bluish-gray, finally becoming dark gray or brown.

SELF-TESTING EXERCISES (P. 172). 1. (*a*) Heating materials. (*b*) Dissolving the materials, or mixing them with water. (*c*) Exposing materials to light.

2. *Exp. 11:* heating; *Exp. 12 b:* mixing with water; *Exp. 13:* heating; *Exp. 14:* heating; *Exp. 15:* mixing with water; *Exp. 16:* exposure to light.

PROBLEMS TO SOLVE (P. 172). 1. Light has caused a chemical change in the dyes of the cover cloth so that they have faded.

2. The light acts on the dyes (colored compounds) in the paper to change the color except where the picture has protected the paper from light.

3. Heat, light, and moisture in various text experiments. Pupils may mention such original experiences as (*a*) exposing, developing, and printing photographs; (*b*) dissolving when putting baking powder in cake batter; and (*c*) heating when gas, wood, etc., are burned for cooking.

4. Gasoline burns and changes from gasoline to certain gases, and finally to carbon dioxide and water.

Heat makes the change take place.

EXPERIMENT 17. HOW MAY ONE KIND OF CHEMICAL CHANGE BE PREVENTED? (P. 173). The apparatus and materials needed are: piece of bright iron (a nail), paint, brush, glass jar with cover, sponge, water, knife (or scalpel) for scraping.

An interesting variation of this experiment is to use bright steel wool. One piece of wool may be dipped or sprayed with oil, while the other is untreated.

SELF-TESTING EXERCISES (P. 174). 1. (*a*) Keeping apart materials that can combine; (*b*) keeping out of light; (*c*) keeping heat away—keeping cool; (*d*) keeping water away—keeping dry.

2. In Experiment 17 pupils kept materials apart (iron and oxygen). Original experiments may include: (*a*) keeping light away from films when loading a camera; (*b*) keeping things cool in icebox; (*c*) painting bicycle or drain pipes on house; (*d*) keeping oxygen out of bottles of some kinds of medicine; (*e*) keeping food cool.

PROBLEMS TO SOLVE (P. 174). 1. Sunlight may cause a chemical change in the dyes so that the colors fade.

2. If it gets wet, a chemical change will take place, and the baking powder in the flour will no longer be effective.

3. Heat has brought about a chemical change, leaving black carbon.

4. To prevent chemical changes, which change the sugar in milk to acids and thus cause it to become sour.

PROBLEM 4 (OPTIONAL): WHAT ARE THE TWO KINDS OF SIMPLE CHEMICAL CHANGES? (P. 175)

This problem carries the idea of chemical change one step further than Problem 2 and introduces the use of simple chemical equations for expressing chemical changes more exactly. It is recommended that this problem be studied by all pupils unless there is insufficient time or the previous experiences of pupils are such that they would find it very difficult. Following are the main ideas of the problem:

1. A chemical change in which two or more materials change into one material is called chemical combination. Not all elements can combine to form compounds.
2. Chemists show what happens in a chemical change by writing an equation with symbols and formulas.
3. When compounds are broken up into their elements, the chemical change is called decomposition.
4. Chemists use several methods to decompose compounds.
5. Molecules are made of atoms.

a) Some elements have one atom in a molecule, while others have two atoms.

b) A molecule of any compound will always have two or more atoms.

6. When a chemical change takes place, there is always a change in the number or kinds of atoms in a molecule.

SELF-TESTING EXERCISES (P. 179). 1. They unite to form a new substance with characteristics of its own.

A compound is produced.

2. (*a*) That it separates into the elements of which it is made or into elements and other compounds. (*b*) A compound.

3. Both combination and decomposition ("Combination" should be considered an adequate answer.)

4. (*a*) Lost its red color; (*b*) was changed into a liquid and a gas; (*c*) was no longer a compound but was separated into the elements of which it was formed.

5. Molecules of one substance may combine with molecules of another substance to form a new kind of molecules, or molecules may be decomposed into their atoms.

PROBLEMS TO SOLVE (P. 179). 1. Combination.

2. Because the dangerous characteristics of the elements making up the compound are changed when they combine to form the compound.

3. Decomposition. Because the material of the candle has been separated by heat from the flame into carbon, carbon dioxide, and water vapor.

4. Decomposition.

LOOKING BACK AT UNIT 5 (P. 180). Refer to the graph on page 120.

1. Pupils may be expected, with individual variations in phrasing, to state the following ideas:

a) Chemical changes are going on around us all the time.

b) Elements cannot be separated into simpler materials.

c) Compounds can be separated into two or more elements, but we cannot tell by looking at a compound what elements are in it; chemical tests are necessary to determine this.

d) Every substance has certain characteristics by which a chemist can tell what it is.

e) When a chemical change takes place in substances, the characteristics of the substances are changed, and the new materials have different characteristics from the original ones.

f) Many materials are mixtures of substances, either elements or compounds or both. In making mixtures no chemical change takes place.

g) Chemical changes can be started or prevented in various ways, depending on the substances being used.

2. There will be variation in the phrasing used by pupils to define or explain these science terms:

A *chemical change* is a change that results in a new material or materials with different characteristics from the original material.

A *compound* is a material that contains two or more simple materials (elements).

A *formula* is an expression or abbreviation for a compound that shows by symbols which elements (and how much of these elements) make up that compound.

An *element* is a material that cannot be separated into simpler materials.

A *chemical symbol* is made up of the letter or letters that stand for an element, as O for oxygen.

A *mixture* is a material made up of different substances (elements or compounds or both) put together without a chemical change having occurred.

ADDITIONAL EXERCISES (P. 180). 1. An important characteristic of carbon disulphide is that it catches fire very easily. A chemical change takes place very rapidly when air and carbon disulphide fumes come together.

2. Yes. The solid chemicals in the baking powder react when dissolved in water to form a substance (carbon dioxide), which is a gas at ordinary temperatures.

3. Would burn completely. The heated charcoal as well as the gases would burn. Only the minerals that could not burn would be left.

4. Copper is changed in some way to form a compound. (The exact change is that copper combines with carbon dioxide of the air, forming copper carbonate.)

5. To prevent heat from causing a chemical change that would change the characteristics of the medicine. Also, to prevent bacterial action that might bring about chemical changes.

6. Evidences of chemical change: (*a*) Black or dark brown residue in tube; (*b*) smell of burning sugar; (*c*) cloud of steam given off.

The water that comes off and the black material (carbon) left in the tube show that sugar is a substance containing at least carbon, hydrogen, and oxygen, and is therefore a compound.

7. Yes. (Calcium oxide plus water makes calcium hydroxide plus heat.)

We know this because a great amount of heat is formed when the quicklime is put into the water. The giving out of heat is characteristic of many chemical reactions; some give out much more than others.

BULLETINS AND PAMPHLETS FOR UNIT 5

Agriculture Circular
  No. 138. *Development and Use of Baking Powder and Baking Chemicals.* 5c
Agriculture Yearbook Separate
  No. 1659. *General Chemistry of the Soil.* 10c

VISUAL MATERIALS FOR UNIT 5

Motion Pictures

Alpha Cement Company, Easton, Pa.
  "Cementing the Centuries" (free)
National Lead Company, 111 Broadway, New York, N. Y.
  "What Price Painter" (free)
Viscose Company, 171 Madison Ave., New York, N. Y.
  "Romance of Rayon" (free)

UNIT 6

How Do We Use and Control Fire?

FUNCTION AND SCOPE OF UNIT 6. One of the greatest steps that man has made in learning about and using the resources of his surroundings has been his discovery of the uses and the nature of fire. Prehistoric man used fire, but he did not understand its nature. The greatest advances in the use of fire have been made since man learned its nature and devised better ways of controlling it. Its use has made possible the growth of our industrial world.

The study of fire in this unit should do for the individual what the study of fire has done for the race: It should open his eyes to the nature and importance of this great chemical change and enable him better to use and control it.

Of special significance in the unit is the problem of preventing accidental fires; only through careful education shall we be able to reduce the high annual fire loss in property and lives. This education can best be based on real understanding of fire as well as on instruction in practical details of its application.

This unit can best be understood if pupils have learned about the three states of matter in Unit 3, the effect of heating and cooling materials (changes of state) in Unit 4, and elements, compounds, and chemical change in Unit 5.

The understanding of the essentials of fire, of oxidation and energy release, will be helpful in a number of later units in this book: In Units 8, 9, and 11 in the discussion of the nature of carbon dioxide given out by plants and animals and used again by plants; and in Unit 10 in the discussion of why our bodies need food and what they do with it.

In *Book 2* the ideas are used again as follows: the different forms of energy and their changes (Unit 5); how we keep our buildings warm (Unit 6); keeping our cells alive by oxidation (Unit 8).

The graph on page 137 will help in selecting the points to be emphasized in the study of the unit.

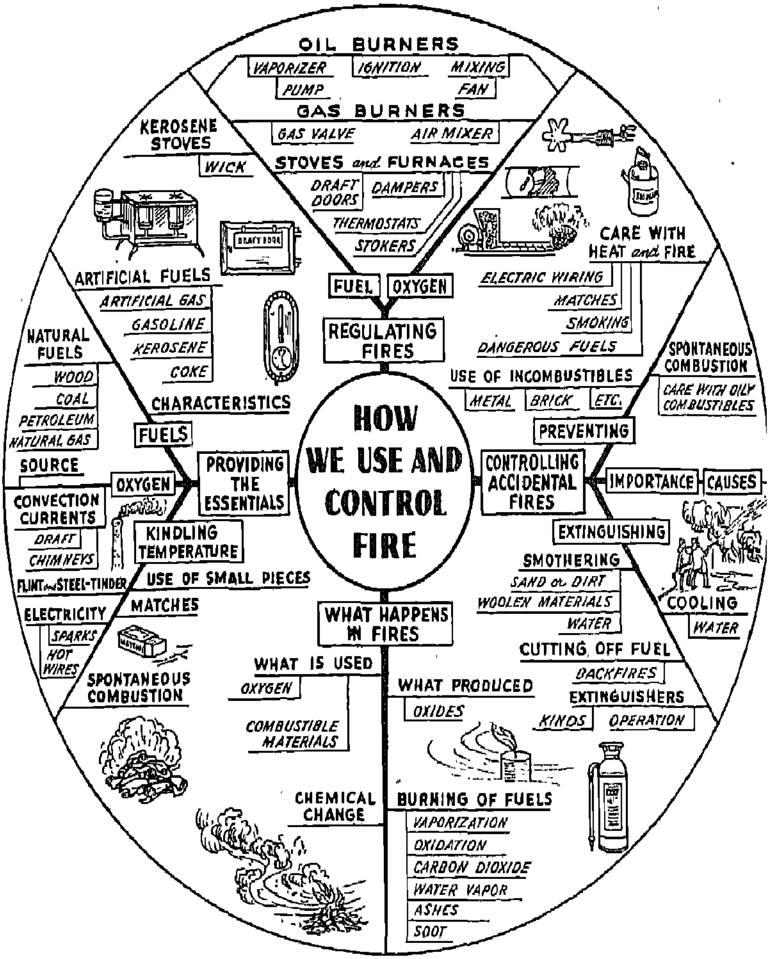

FIG. 9. GRAPH OF THE SUBJECT MATTER OF UNIT 6

INTRODUCTORY EXERCISES (P. 182). 1. Changed (to various gases which are finally combined with oxygen) to form carbon dioxide and water vapor. Both these invisible gases mix with air above candle.

2. Yes. Material of candle is changed into other things with different characteristics—specifically, carbon dioxide and water.

3. Some fires that may be listed:

LIST OF FIRES	WHAT EACH FIRE DID
1. Fire in the fireplace.......	*Kept us warm.
2. Fire in the furnace........	*Kept the house warm.
3. Fire in the incinerator.....	*Burned up the rubbish. Made smoke and unpleasant odor.
4. Fire in the kitchen stove...	*Cooked our meals.
5. Forest fire	Burned much valuable lumber and killed many animals.
6. Camp-fire	*Cooked our food; kept us warm.
7. Fires in steel mills, etc.....	*Melted iron ore and steel for making many things.
8. Fire in a locomotive......	*Heated water, making steam for power.
9. Houses, etc., burning down.	Destroyed much property; injured many people.

4. (a) A material that will burn. (*b*) Heat enough to heat the material to its kindling temperature. (c) Enough oxygen.

5. Amount of oxygen fires can get; amount of fuel supplied.

Camp-fire. Both methods are used. To a certain extent the arrangement of fuel controls the supply of oxygen, but the amount of fuel is the main method.

Coal furnace. The fire is usually regulated by the amount of air given the fire. Occasionally, control is partly by the amount of fuel supplied.

Gas-burner. Amount of fuel is regulated.

6. Pupils may list some of these ways: (a) Put water on. Keeps oxygen away; lowers temperature.

b) Put sand or dirt on fire. Keeps oxygen away from combustible material.

c) Roll in wool blanket. Keeps oxygen from fire.

d) Put baking soda on burning fat. Keeps oxygen away and prevents spreading.

e) Pull sticks out of a camp-fire. Removes fuel from main fire, and each separate stick cools off and "goes out."

7. Answers may vary and still be acceptable. (a) Carelessness in setting bonfires.
b) Carelessness in throwing away cigarette stubs.
c) Defective wiring in buildings—poor insulation.
d) Storing bunches of oily rags, papers, etc., where spontaneous combustion can occur.

These fires could be prevented by correcting these mistakes.

LOOKING AHEAD TO UNIT 6 (P. 183). This unit is one that is very easy to introduce. The teacher may well tell the story of Prometheus (see a Greek mythology book or an encyclopedia) and raise the question of why fire was considered a worthy possession of the gods. Pupils may then read the preview in the book and explain as many of the italicized statements as they can. Pupils should not be allowed to accept as satisfactory explanations that are too elementary or superficial. A little quizzing by the teacher about the source of light and heat and about where the wood really goes will help the pupils feel that there is really something to be understood.

PROBLEM 1: WHAT HAPPENS WHEN THINGS BURN? (P. 186)

The answer to Problem 1, if grasped by the pupil, forms the foundation for a real understanding of each of the later problems. The teacher should not be satisfied until practically every pupil really "gets" the main ideas—the answer to the problem. The main ideas may be stated briefly:

1. Burning is a chemical change in which oxygen from the air unites with the burning material, with the production of heat and light, and changes it into another material or other materials, which are compounds of oxygen, called oxides.

2. A chemical change in which oxygen combines with a material is called oxidation; burning and rusting are both oxidation.

3. Our common fuels are composed in large part of compounds of carbon and hydrogen.
a) The oxides that result from their burning are carbon dioxide and water vapor; both are invisible and mix with the air.

b) The ashes are the substances that do not form gases.

c) Black smoke and soot from fires are carbon that has not burned.

4. Partial union of carbon with oxygen produces a poisonous gaseous oxide, called carbon monoxide.

Experiment 18. What Happens to Magnesium When It Is Burned? (p. 186). The apparatus and materials needed for the experiment are:

Magnesium ribbon, thirty inches (or six inches and one teaspoon magnesium powder)
Pliers (or forceps)
Small tin can lid with wire hanger (or porcelain crucible and pipestem triangle)
Ringstand with ring
Bunsen burner (or other source of high temperature)
Balance (See p. 86 for homemade balance.)
Dry sand

This experiment is introduced because oxide of magnesium is a solid that is tangible and shows that the product really weighs more than the material that burned. The experiment is more effective if performed before the pupils have done any reading.

Experiment 19. What Happens to the Air in Which Iron Rusts? (p. 187). The apparatus and materials needed are:

One teaspoon iron filings (or wad of steel wool one inch long)
Two large glasses (Fig. 129)
Water
Two test-tubes
Two corks to fit test-tubes
Wooden splinters, six inches long
Matches

a) The directions are given in detail. A wad of steel wool pushed to the very bottom of a test-tube is a very satisfactory substitute for iron filings. No harm is done if the results are not observed for several days.

b) The burning splinter usually goes out instantly in the tube where rusting has occurred but continues to glow for a time in the other. Care must be taken to avoid touching the inside of the wet tube with the burning splinter. Be careful also not to allow fresh air to enter the first tube before the test is made.

Experiment 20. What Happens When a Candle Burns? (p. 192). The apparatus and materials called for are:

Four candles (one short)
Cardboard squares (or other holders for candles)
One foot wire, iron or copper, small enough to be bent easily
White dish (or plate)
Two one-pint or half-pint glass jars (or wide-mouth bottles)
Glass cover for one jar
Limewater
Matches

To make limewater add a handful of calcium oxide or hydrated lime to distilled water in a large, stoppered bottle. Shake occasionally. After allowing it to stand for several days, pour the clear solution into a smaller bottle for use. Again fill the large bottle. The lime will make several gallons of limewater.

a) If the match stick is held in the center of the large candle flame for the right length of time and *quickly* extinguished, it will show two scorched places with a lighter band between.

When the second part is done properly, the flame will run down the stream of wax vapor and ignite the wick again. This indicates that the wax leaving the wick inside the flame is in a gaseous condition.

b) This part should present no difficulty.

c) and (d) Both these parts give good results. If gas is available, both may be repeated with a gas flame. For part d, invert the jar over the flame, and, as it is removed, cover the top with the glass cover.

Self-Testing Exercises (p. 196). 1. Because oxygen is added to it to form the compound, magnesium oxide. The weight of the oxygen is thus added to the magnesium.

2. Yes. An experiment like 19 shows it—water rises in the tube.

3. Both are types of chemical changes (oxidation) in which materials combine with oxygen to make new substances.

Burning is oxidation that takes place very rapidly, while rusting is oxidation that takes place very slowly.

4. Carbon dioxide and water.

Most materials we burn are made up of carbon and hydrogen compounds. When these burn, oxidation takes place, carbon and hydrogen combining with oxygen to form carbon dioxide and water vapor.

We can see that carbon dioxide is formed by testing for it with a little limewater. Water vapor can be seen by allowing it to condense on a cool glass or other cool object.

5. Because the substances change from solid or liquid state to compounds in gaseous state that we cannot see as they go off into the air.

In fuels only the minerals that do not burn are left.

6. Rapid combining of a material with oxygen, accompanied by heat and light.

Problems to Solve (p. 196). 1. Pupils at this stage should not be expected to explain all the points. In many cases this problem should be postponed until the class has completed the study of the unit. For complete explanations of these points see Problem to Solve 4 (p. 225), page 155 of this *Guidebook*.

2. When wood burns, oxidation is so rapid that much heat is formed. Materials in wood are changed into gaseous form. The flame is really a stream of burning gas. A flame gives out light because the gas contains solid particles of carbon from the materials in wood. Heat makes these particles glow and give off light. This gives a flame of luminous yellow color.

3. Because, in preparing coke, most of gas-forming elements have been driven off, and the coke left is almost pure carbon, which does not form a gas when heated in a fire. Coal contains materials that form streams of burning gas, or flames.

4. From burning of gas. It comes off in the form of gaseous water, or vapor, but when it strikes the cold kettle, it condenses to liquid form.

5. No. The wire is heated until it glows, but it does not really burn because it is not used up and does not disappear. Burning

is oxidation, and since all air has been withdrawn from the bulb, burning of the filament cannot take place.

6. This experiment can usually be done successfully by careful workers. Heating the glass tubing in a flame just before putting it in the candle flame prevents condensation of the wax vapor and makes the demonstration more successful.

PROBLEM 2: HOW DO WE MAKE FIRE? (P. 197)

This problem deals with the practical application of the principles learned in answer to Problem 1, so that the pupils may be able to manage fire for themselves. More specifically, its solution is an understanding of how fires are provided with the conditions essential for burning. This understanding is prerequisite to Problem 3, which deals with the practical details of controlling a fire that is already burning. The main ideas that provide the solution of Problem 2 are:

1. For a fire there are three essentials: (a) a combustible material, (b) a supply of oxygen, and (c) a temperature high enough to start the burning.

2. Heat to start burning is commonly obtained from another fire, from friction or impact, from electrical current, or from slow chemical action. The matches we use for this purpose are made of chemicals that ignite easily from the heat of friction.

3. The oxygen for most fires is obtained from air, which is about one-fifth oxygen. Convection currents caused by the heat of the fire bring a constant supply of fresh air and remove the used air. Chimneys make these currents stronger.

4. The combustible materials suitable for our useful fires are fuels.

a) The requirements of a good fuel are that it must burn rather easily, give off large amounts of heat, and be available at a reasonable cost in sufficient quantities to supply demands.

b) Coal and petroleum are the most important natural fuels, and from them we get such artificial fuels as coke, gas, gasoline, and fuel oil.

EXPERIMENT 21. HOW DOES A FIRE GET ITS SUPPLY OF FRESH AIR? (P. 200). The apparatus and materials are: Candle (or kerosene lamp); punk (or touch paper); matches.

Touch paper may be made by soaking filter paper or a paper towel in a saturated solution of potassium nitrate (saltpeter) for a few minutes. Let the paper dry for at least a day before it is to be used. For use roll it into a tight roll and light one end of it.

The experiment itself involves no difficulties. The convection currents that are studied are commonly misunderstood. There is a general feeling that "heated air rises" and leaves a space into which other air moves. Heating air does not cause it to lose its weight, but only to become less dense (to weigh less per cubic foot) because of *expansion*. The process described in the reading material then occurs, causing the convection current.

EXPERIMENT 22. WHY DOES A CHIMNEY HELP A FIRE BURN BETTER? (P. 201). The apparatus and materials are: Kerosene lamp with a clear glass chimney; a supply of kerosene; punk (or touch paper); matches.

This experiment should make clear the fact that the convection current flows much more rapidly through a chimney than it does without a chimney. If possible, the class should visit a fireplace or furnace and test the draft caused by a fire. This may be done by use of smoke from punk or touch paper or by dropping bits of light material into the air current. (If combustible materials are allowed to be carried up the chimney, the instructor should first make sure that there is no danger of starting an accidental fire.)

SELF-TESTING EXERCISES (P. 202). 1. (a) A combustible material, (*b*) heat enough to start the burning, and (c) a supply of oxygen.

2. (a) Obtain materials that will burn, such as paper and wood. *b*) Start the fire with small pieces of material that will begin to

burn easily, such as paper or shavings. Then use larger and larger pieces that will be set on fire by heat from the small pieces until the largest pieces of wood are burning.

c) Arrange the materials in such way that currents of air will carry plenty of oxygen to the materials to be burned.

3. (*a*) Using friction, (*b*) using chemical action, (*c*) using electricity.

4. Slow oxidation of some material, such as oily rags, under conditions that keep the heat of this chemical change from escaping into the air.

Eventually enough heat collects to raise the temperature of materials inside the heap of rags, etc., to the kindling temperature, and they catch fire, or burst into flames.

5. By a large convection current similar to that shown about *the candle of Figure 138, page 201, of the text.*

6. (*a*) By arranging the pieces of fuel so that air gets to them easily.

b) By speeding up convection currents with chimneys and fans so that a fresh supply of air is constantly brought to the fire.

7. (*a*) To give a better supply of oxygen to the fire; (*b*) to carry off smoke and sparks.

8. Matches that strike anywhere have all the chemicals they need in the match head. Those that must be rubbed on the box have some chemicals in the match head and some in the material on the side of the box.

PROBLEMS TO SOLVE (P. 202). 1. Oxygen is the gas needed for burning. Only one-fifth of the air is oxygen. When all the gas that touches the spark is oxygen, it burns so much faster that the fire increases in size and brightness very quickly.

2. Convection currents set up by the terrific heat of the fire become so strong that movement of air along the earth's surface becomes strong enough to be called a wind.

3. Makes air move and thus brings a fresh supply of oxygen to the fire.

4. Magnifying-glass concentrates all the rays of sunlight that strike glass at one spot on some combustible material. Temperature of this spot rises above its kindling temperature, and it begins to burn.

5. This test is made by placing the materials to be tested at equal distances from the center of a metal plate. The burner is placed exactly below the center of the plate. The materials then ignite in the order of their increasing kindling temperature.

The match head, composed largely of phosphorus sulphide, usually ignites first; then the sulphur, and last the wood and paper. The latter two have very close to the same kindling temperature since the paper is made from wood fiber. (The piece of wood should be quite small.)

6. In a friction cigar-lighter a piece of metal alloy, that makes sparks easily, rubs against a rough steel wheel or steel file. The sparks strike a wick saturated with some easily ignited liquid. The essentials should be stated by the student.

EXPERIMENT 23. HOW ARE COKE AND GAS MADE FROM SOFT COAL? (P. 205). The apparatus and materials needed for this experiment are:

- Ringstand and clamp
- Test-tube
- Soft coal, finely crushed
- Rubber or wet clay stopper, one-hole
- Small glass tube, four inches long
- Bunsen burner (or other source of high temperature)
- Matches
- Hammer (or other hard object to break test-tube)

This experiment usually causes no difficulty. An interesting variation may be of interest to students who have opportunity to carry out projects. By passing the gas through a wide-mouthed bottle fitted with a two-hole stopper and glass tube, coal tar from the heated coal can be collected in the bottle, and the gas can be burned as it comes out of the bottle. This can be shown, and a talk can be made on the substances obtained by chemists from coal tar.

SELF-TESTING EXERCISES (P. 207). 1. Some are too expensive; some are too hard to ignite; others are too bulky.

2. In addition to data from the textbook, the table on page 147 includes advantages and disadvantages that pupils may well be expected to suggest from common experience with fuels.

FUELS	ADVANTAGES, OR GOOD CHARACTERISTICS	DISADVANTAGES
NATURAL		
Wood	Low burning temperature; burns continuously if air supplied.	High cost; lower fuel value than coal.
Hard coal	Burns slowly; clean; burns with little smoke.	High cost; hard to kindle.
Soft coal	High fuel value; easy to kindle; burns rapidly; less expensive.	Much smoke and fuel dust; dirty fuel.
Crude oil	Low kindling temperature; burns rapidly; cheaper and cleaner for many uses; higher fuel value than coal.	More expensive than coal.
Natural gas	Low kindling temperature and can be ignited with ordinary match; good heat-producing qualities; burns rapidly and produces maximum heat at once.	High cost when it must be piped long distances.
MANUFACTURED		
Gasoline	Quick source of heat; clean; economical; can put out the fire when through with it.	Explodes easily and dangerous to have around home.
Coke	Produces intense heat; almost no smoke.	Hard to start burning.
Kerosene	Same as for gasoline.	Inflammable and may lead to fire hazards in home.
Charcoal	No smoke; gives intense heat.	Expensive.
Coal gas	Low kindling temperature; high fuel value; burns rapidly; no smoke if well regulated; instantly available for use.	Expensive in most regions; some danger from carbon monoxide.

3. Soft coal is heated without air. Gas that comes off passes through an opening in the coal container and is purified and collected for future use.

4. In the earth; sometimes above petroleum in oil wells; and sometimes in places where there is no oil.

It is used as fuel for heating, lighting, and power.

5. Oil is heated, and the compound that evaporates most easily is changed to a vapor first, is collected, and is condensed to a liquid. Oil is heated again to a higher temperature, and the next compound comes off and is condensed. Gasoline comes off first; then kerosene. (This process is known as fractional distillation.)

Gasoline is more important as it is much more widely used for fuel in engines, especially in automobiles and airplanes. (Pupils' answers to the second question may be the basis of a class discussion.)

PROBLEMS TO SOLVE (P. 207). 3. The fire is not receiving enough air, or the fuel is not yet hot enough. Not all gases from the coal are being burned, and much unburned carbon is escaping as black smoke.

The condition may be remedied by regulating the amount of fuel given or the air supplied to the fuel. If too much fuel is put on before the fire is hot enough to burn the gases, they will pass off as smoke. If not enough air is supplied, incomplete burning will take place and much carbon will be unburned.

4. Class trip and report. See discussion of such trips on page 39.

5. Fuel value means amount of heat produced when a fuel burns. Fuel value is usually measured in British thermal units (B.T.U.'s) per pound. One B.T.U. heats one pound of water one degree Fahrenheit.

Fuel value of substances named are as follows: Hard coal, about 13,600 B.T.U.'s per pound; soft coal, about 14,000 B.T.U.'s per pound; wood, 5800 B.T.U.'s per pound.

PROBLEM 3: HOW DO WE REGULATE FIRE? (P. 208)

The solution of this problem leads to a further understanding of fire and especially of the commoner devices used to make fire most effective by controlling it more effectively. Real understanding requires grasp of the main ideas of Problems 1 and 2. The main ideas to be developed are:

1. Fires are commonly regulated by controlling the supply of oxygen or the supply of fuel or both.
2. In stoves and furnaces that burn solid fuels, the rate of burning is regulated largely by controlling the supply of oxygen through the use of draft doors and dampers.

a) Thermostats regulate temperature automatically with the help of electric motors.

b) Electric stokers regulate fires better than can be done by hand firing, because they feed the fuel in at the correct rate and force it in at the bottom of the fire.

3. In kerosene-burners the supply of fuel is usually controlled by raising or lowering the wick.

4. In gas-burners the nature of the flame is regulated by the proportion of air mixed with the gas. The size of the fire is regulated by the amount of fuel.

5. Oil-burners change the oil to a vapor or fine mist and mix it with the right amount of air. The size of the fire is regulated by the amount of oil fed in by a pump.

EXPERIMENT 24. HOW DOES A BUNSEN BURNER WORK? (P. 212). The apparatus and materials are: Bunsen burner; gas supply; matches (or gas lighter); wire gauze (or piece of screen wire); white plate or dish.

In regions where gas is not a common fuel, this experiment will have little significance, and it must, of course, be omitted if gas is not available in the school. In such cases a special study of some other kind of burning device should be planned.

a) A slender, yellow flame is produced. Often it vibrates and makes a slight "roaring" sound when the full pressure of the gas is turned on.

b) When the holes are closed, there is usually a large, wavering, yellow flame. With the holes open to admit air, the flame is reduced in size and light blue in color with a greenish-blue central cone. When the flame is blue, there is sufficient oxygen to allow complete combustion to take place throughout the flame. (See the explanation for part d, p. 150.)

c) At the base the center of the yellow flame is composed of cold gas; about the edge the wire may become dull red as the gauze is moved upward. This red-hot area spreads to cover a comparatively large spot in the upper parts of the flame.

The center of the base of the blue flame is also cool. (A match head can be held here without igniting it.) The gauze will show the very brightest color in the center of the flame just above the central cone. No more gas is burning in the blue flame than in the yellow flame; so the higher temperature of the blue flame is due to the fact that the gas is burning in a smaller space. Glass can be melted most rapidly in a blue flame, just above the central core.

d) Heating of the gas without air in the center of the flame decomposes it and produces, among other things, particles of carbon. These are "yellow-hot" and make the flame yellow. They burn when they reach the air unless they are cooled by contact with some cool object, such as the dish. In the blue flame the carbon is oxidized as fast as it is produced.

This part of the experiment shows what must be done to stop the smoking of pots and pans by a gas burner.

SELF-TESTING EXERCISES (P. 215). 1. Fires are regulated by controlling the amount of fuel or the amount of air, or both, so that the best conditions for burning and the desired amount of heat or light are obtained.

2. (*a*) *Stoves (coal or wood) and furnaces (coal-burning)*. By regulating both the amount of air admitted and the amount of fuel supplied to the fire, but mainly the former. The amount of air admitted is regulated by opening or closing draft and damper, as desired. The amount of fuel also affects the oxygen supply, as too much fuel smothers a fire. The amount of ashes in the furnace also helps regulate the oxygen supply.

b) *Kerosene stove*. By regulating the amount of wick exposed to the flame and therefore the amount of kerosene that will evaporate and burn.

c) *Gas-burners*. By regulating both the amount of air and the amount of gas that enters the burner. The amount of gas is controlled by a cock in gas line that can be opened or closed to admit more or less gas. Air is regulated by shutters over openings in the air-and-gas mixing chamber. These can be opened or closed to admit more or less air. This regulates the kind of flame, while the amount of heat is determined by the amount of gas admitted.

d) *Oil-burning furnaces*. By regulating the amount of oil sent through to be vaporized.

3. In a coal fire the amount of heat is regulated mainly by the amount of air supplied to the fuel. In a gas fire the amount of heat is regulated by the amount of fuel supplied.

PROBLEMS TO SOLVE (P. 215). 1. Answers will vary. One answer might be: Gas is a very desirable fuel to use, as it has a high fuel value, kindles very easily, burns without smoke, leaves no residue to be taken care of, and is always available, that is, the individual supply does not run out.

2. Results variable. A report to the class is desirable.

3. Drawings will vary. They should be diagrammatic rather than pictorial and of such nature that they will help the pupil learn how the furnace really works.

A chain is connected to the draft door and to the "check draft" and is run up through holes in the floor to a place on the baseboard of the room above the furnace. The chain passes over a wheel with teeth in it. By turning this wheel, the chain will open check and close draft, or vice versa. Some furnaces have separate chains for draft and for check. (The check draft opens and closes a hole in the smoke pipe to regulate the strength of the draft. Usually a damper inside the pipe is also provided.)

4. Answers variable. Figure 149 may well be used as a pattern. Modern gas stoves have different types of burner construction, but all operate in a similar way: When a valve is turned on, gas flows through a tube into the burner head, drawing air with it from the open air-mixer at the valve end of the tube.

5. Because oil in an oil-burner must be vaporized before it will burn, while gas can burn as soon as it reaches the air and is ignited.

PROBLEM 4: HOW DO WE PREVENT AND EXTINGUISH ACCIDENTAL FIRES? (P. 216)

Fire prevention is one of the important problems of everyday life and is, therefore, part of the training that should be given every citizen. In the science class such training can be connected with the scientific principles on which it is based and thus be doubly effective. Local fire departments are almost always glad to coöperate in explaining their quarters, equipment, and methods, both at the fire station and at school assemblies. The main ideas in the solution of the problem are:

1. Most fires are caused by careless handling of fire and fire materials, by electricity, and by faulty construction of heating devices and buildings.

2. Fires never occur if combustible materials are kept below their kindling temperature.

3. Fires are prevented by constant care and avoidance of certain dangerous practices which allow combustible materials to be overheated by useful fires, electric devices, matches, or spontaneous combustion.

4. Fires are extinguished by cutting off the air supply or the fuel supply, by cooling the burning material, or by a combination of these methods.

5. One type of chemical extinguisher is merely a convenient device for squirting water where it will do the most good; other types produce heavy gases for smothering fires.

EXPERIMENT 25. HOW DOES CHEMICAL ACTION PUSH THE WATER OUT OF AN EXTINGUISHER? (P. 221). The apparatus and materials for this experiment are:

Part a

Glass jar, one quart capacity
Water
One pound baking-soda (enough for both parts)
Vinegar (or dilute sulphuric acid). (NOTE: Always dilute a concentrated acid by pouring the acid slowly into water while stirring it.)
Candle

Part b

Milk bottle (or strong wide-mouthed bottle)
Stopper, one-hole, to fit bottle
Baking-soda
Sulphuric acid, 50% solution
Material for fastening stopper in securely (wire, strong cord, clamp)
Twenty inches wire, No. 22 iron or copper
Small glass or copper tube
Homeopathic glass vial
Rubber hose with glass nozzle

a) The flame goes out because the jar is filled with carbon dioxide, in which the candle cannot burn.

b) If possible, use a model fire extinguisher, such as is available from apparatus companies. Only the teacher should do this part of the experiment, being careful to fasten the stopper securely. (CAUTION: If a bottle is used, wrap it in heavy cloth to avoid injury in case gas pressure should burst the bottle.)

Properly carried out, the experiment helps pupils to be intelligent about the very common carbon-dioxide extinguisher. Often the coöperation of the school janitor or custodian can be enlisted in an outdoor demonstration of a real extinguisher, since these extinguishers must be periodically discharged and refilled to keep them in working condition.

EXPERIMENT 26. HOW DOES CARBON TETRACHLORIDE PUT OUT A FIRE? (P. 222). The apparatus and materials needed for this experiment are:

Part a

- Two or three tablespoonfuls, or two ounces, carbon tetrachloride
- Deep metal pan (or one-half gallon jar)
- Cover to fit pan or jar
- Large beaker (or one-half pint glass jar)
- Candle
- Matches

Part b

- Two tablespoonfuls gasoline or kerosene
- Four ounces carbon tetrachloride
- Small dish
- Large flat pan
- Asbestos to set beneath pan
- Matches
- Water

a) Candle goes out because carbon tetrachloride vapor, which is heavier than air, settles down over burning candle and keeps air away.

b) Carefully carried out, this demonstration seldom fails to work satisfactorily. Some unpleasant fumes and soot are given off; so the room should be aired after the demonstration is over.

From this part pupils should see that when water is poured on a gasoline fire, it really spreads the gasoline, which is lighter and floats on top of the water. Water and gasoline do not mix. Carbon tetrachloride mixes with gasoline, and when a certain percentage of the mixture is carbon tetrachloride, the gasoline can no longer burn. The smothering effect of the fumes also helps.

SELF-TESTING EXERCISES (P. 224). 1. Answers will vary. Pupils should make use of Table 7 on page 217 of the text.

3. The carbon-dioxide fire extinguisher contains a solution of baking-soda and water and a bottle of concentrated sulphuric acid. When the extinguisher is turned upside down, the sulphuric acid and baking-soda react, forming a large amount of carbon dioxide. Pressure of the gas forces a stream of water from the extinguisher. This lowers the temperature of the burning substance and shuts off the supply of air.

4. When carbon tetrachloride is poured onto a fire, heat changes the liquid to gas. The vapor from the liquid is much heavier than air and settles down on the fire. This prevents the access of air for a long enough time to stop the fire.

Water will spread gasoline fire, since gasoline will float on water. Gasoline will mix with carbon tetrachloride, however, and when a certain percentage of the mixture is carbon tetrachloride, gasoline will no longer burn.

5. Try another kind if at hand, depending on kind of fire. If there is still a chance of stopping the fire, use some method suitable to that kind of fire. Call for help and send for the fire department as soon as possible.

6. Depending on kind of fire, would use water or sand or dirt to put it out. If a person's clothes caught on fire, he could be wrapped in a woolen blanket or something else woolen in order to smother flames. In kitchen, burning fat could be put out by using baking-soda. If a public fire department is available and the fire is spreading, call the fire department.

PROBLEMS TO SOLVE (P. 225). 2. Answers will vary. Both this and Problem to Solve 1 are good committee projects that should be reported to the class when completed.

3. (*a*) They become large before anyone finds them or attempts to put them out.

b) Wrong methods are used in trying to put them out, so that they spread instead of being controlled.

c) Fires start in inaccessible places, such as in attics or in walls.

4. *Cleared away the twigs and leaves from a wide space.* To prevent the fire from catching on these materials and spreading to the trees in the forest.

Brought in the fallen branches of trees. To provide combustible material, one of the three essentials.

Chose a dry stick. A dry stick has a lower kindling temperature than a wet one.

Made a little pile of shavings and splinters. They get hot more quickly than a large stick, and more air can come into contact with wood.

Rubbed one end of it on the box. Was using a safety match that would light only when struck on the especially prepared material on the side of the box. Rubbing produced heat.

The match took fire. The heat resulting from friction of the match head on the box was enough to start the chemicals burning. Then they kindled the wood in the match stick, and it began to burn.

Small sticks. They get hot more quickly than large ones.

Loosely. To let plenty of air get to the sticks.

Fire was giving enough light. Fire gives out so much heat that the materials produce light.

(Smoke) passed upward. Warm air around a fire is lighter than cool air and is pushed up by the surrounding cool air.

Fire gave out heat. When oxidation takes place; a great deal of heat is produced. Burning is a very rapid combination with oxygen.

Great pile of wood was gone. The burning involved a chemical change in the fuel. Much of it was changed from its original form into gases that passed into the air.

Layer of gray ashes. Minerals that would not burn are left.

Pieces of black charcoal. Parts of the wood that were only partially burned, because they did not receive enough oxygen. The black color is due to the carbon from the wood.

Threw water on the fire, etc. Water cools burning material below its kindling temperature and shuts off oxygen. The explorers used this method to make sure that no fire was left to set the forest on fire.

LOOKING BACK AT UNIT 6 (P. 225). Refer to the unit graph, page 137.

1. Strictly speaking, not all of the main ideas below are science principles:

a) Burning is the chemical change that takes place when a material combines with oxygen, and large amounts of heat and light are produced.

b) Fuels contain compounds of carbon and hydrogen.

c) When fuels burn, carbon dioxide and water are formed. These pass into the air as invisible gases, while the minerals that may be present remain as ashes.

d) A flame is produced when materials are changed into gases before they burn; flame is yellow if there are solid, glowing carbon particles in it.

e) To make a fire, we must have a combustible material, a temperature high enough to start burning, and a supply of oxygen.

f) A fire supplies its own air by setting up a convection current.

g) Fires are regulated by controlling the supply of oxygen or the supply of fuel (combustible material) or both.

h) Fires are prevented by keeping combustible materials below their kindling temperature.

i) Fires are extinguished by cutting off the supply of oxygen or the fuel supply, by cooling the burning material, or by a combination of these methods.

2. *Carbon dioxide* is a colorless gas formed when the carbon in most of our common fuels unites with oxygen.

Kindling temperature is the temperature at which a combustible material begins to burn.

Spontaneous combustion is the bursting into flame of materials such as oily rags because of the great heat produced by the uniting of oxygen with the material.

Charcoal is the black material left when wood is heated but not completely burned. It is largely carbon.

Combustible means capable of burning.

Oxidation is a chemical change that occurs when a substance unites with oxygen.

A *thermostat* is a kind of metal thermometer connected with the heating device to control automatically the temperature.

Tinder consists of some very small pieces of some substance that *will burn easily and will take fire from a very few sparks.*

An *oxide* is a compound of some element with oxygen, such as those formed in a fire or in slow oxidation.

ADDITIONAL EXERCISES (P. 225). 1. Answers will vary. May well form basis of a report to class.

2. The flame does not go through the screen because the wires are good conductors of heat. They carry away the heat of the flames so rapidly that the gas on the side away from the flame is not heated to its kindling temperature.

The gases on the outside of the screen cannot be ignited. The explanation is the same as in the first part.

3. *Peat* is an accumulated deposit of mosses and other plant remains that have not decayed because of the chemical conditions where they were deposited. Such conditions are often found in boggy regions of the north. This accumulation of many years is often cut out in blocks, dried, and used for fuel.

Lignite, a dark brown kind of coal, is formed from lower layers of peat. Pressure of an accumulation of top layers presses the material very tightly together.

4. By turning the wick down to reduce the amount of fuel entering the flame; by trimming the wick evenly; by cleaning the base of the burner so that the holes are open.

5. Results vary with pupils and community.

6. Most photo-flash bulbs use aluminum foil as combustible material. It is "set off" by a chemical ignited by an electric current. The white material left inside the bulb is aluminum oxide, a compound formed when aluminum foil burns in oxygen.

7. (a) By electrifying the transportation systems within its limits.

b) By passing and enforcing laws to prohibit smoking chimneys, thus ensuring proper care of fires.

c) By burning hard coal instead of soft coal.

d) By equipping factory chimneys with smoke-consuming devices.

e) By equipping power-plants with automatic stokers for feeding furnaces.

f) By using electricity for power purposes.

8. To put out fires caused by burning gasoline or other materials on which water should not be used as an extinguisher.

9. One blows on a match to drive the gas away from it and thus lower the temperature of the match below its kindling temperature. One blows on a fire to provide a more adequate supply of oxygen and thus speed up the burning. The essential difference is in the effect that dominates.

10. To produce a greater draft. The force producing the draft is caused by the difference in weight between equal volumes of cold and hot air. The longer the column of hot air, the greater its volume will be, and the greater will be the difference in weight between the warm air and an equal volume of cold air.

11. Evaporation of water from wet wood keeps it cool and prevents its igniting until most of the moisture has been driven off. The vapor also keeps oxygen from coming into close contact with the wood.

12. Results will vary. They should be rated on adequacy and on the degree of thought and organization displayed.

13. Determine the volume of the room, which will give the volume of air in the room. Multiply by 0.21 to find out the approximate volume of oxygen. Twenty-one per cent of the air is oxygen.

BULLETINS AND PAMPHLETS FOR UNIT 6

Agriculture Circular
  No. 406. *Oil Burners for Home Heating.* 5c

Department of Agriculture Bulletin
  No. 753. *Use of Wood for Fuel.* 10c

The Diamond Match Company, 30 Church St., New York, N. Y.
  The Romance of the Match (free)
  Fifty Years of Match Making (free)

Farmers' Bulletins
  No. 904. *Fire Prevention and Fire Fighting on the Farm.* 5c
  No. 1786. *Fireproofing Fabrics.* 5c

Public Health Reprint
  No. 694. *Carbon-Monoxide Poisoning in Closed Garages.* 5c

VISUAL MATERIALS FOR UNIT 6

MOTION PICTURES

Commercial Motion Picture Productions, 8634 Sunset Blvd., Hollywood, Calif.
  Fire-prevention films
Eastman Classroom Films
  "Fire Making"
  "Fire Prevention"
  "Fire Protection"
  "Fire Safety"
Pyrene Manufacturing Company, Sales Promotion Department, 560 Belmont Ave., Newark, N. J.
  "Flames, the Red Robber" (free)
U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.
  "Carbon Monoxide: The Unseen Danger" (free)

SLIDES AND FILMSTRIPS

Keystone View Company, Meadville, Pa.
  Unit 10: Heat and Fire (20 slides)
Society for Visual Education, 100 E. Ohio St., Chicago, Ill. (filmstrips)
  "Fire and Fuels"
  "Fire and Heat"
  "In Case of Fire" (National Safety Council)

UNIT 7

How Do Magnets Work?

Function and Scope of Unit 7. This unit presents a simple, well-rounded treatment of the principles underlying magnetism. It is organized so that there is definite relationship between each of its different parts, thus ensuring a smooth progression of ideas as study progresses. For example, a knowledge of what substances are attracted by a magnet (in Problem 1) is necessary for understanding what substances the force of a magnet can pass through and how iron and steel can be made to behave as magnets. Similarly, an understanding of the laws of magnetic poles is necessary for the explanation of the use of compasses. The last problem (optional), "How Is Magnetism Explained?" utilizes the ideas from the entire unit and from the optional problems of preceding units. Refer to the unit graph.

The unit is placed here in the series because of its interest for pupils, because its concepts are grasped easily, and because it is needed later in the work of this series, particularly in Units 5 and 8 of *Science Problems, Book 3*.

In addition, there is a distinct relationship between Problem 3, "Why Do Magnetic Compasses Tell Direction?" and social studies that deal with problems of transportation.

Introductory Exercises (p. 228). 1. (a) True, (*b*) false, (c) true, (*d*) false, (e) false, (f) true, (g) false, (*h*) false, (*i*) true, (*j*) false. (Because of magnetic declination, in only a few places does it point truly north and south.)

2. (a) Yes. The delicate steel springs of the watch would be attracted by the magnet and might be pulled out of place.
b) So that both ends, where the attracting power is strongest, can be brought near the object to be attracted at the same time;
c) A kind of stone that acts as a magnet. It is a kind of iron ore, called magnetite.
d) An electromagnet is like a permanent magnet in its magnetic qualities.

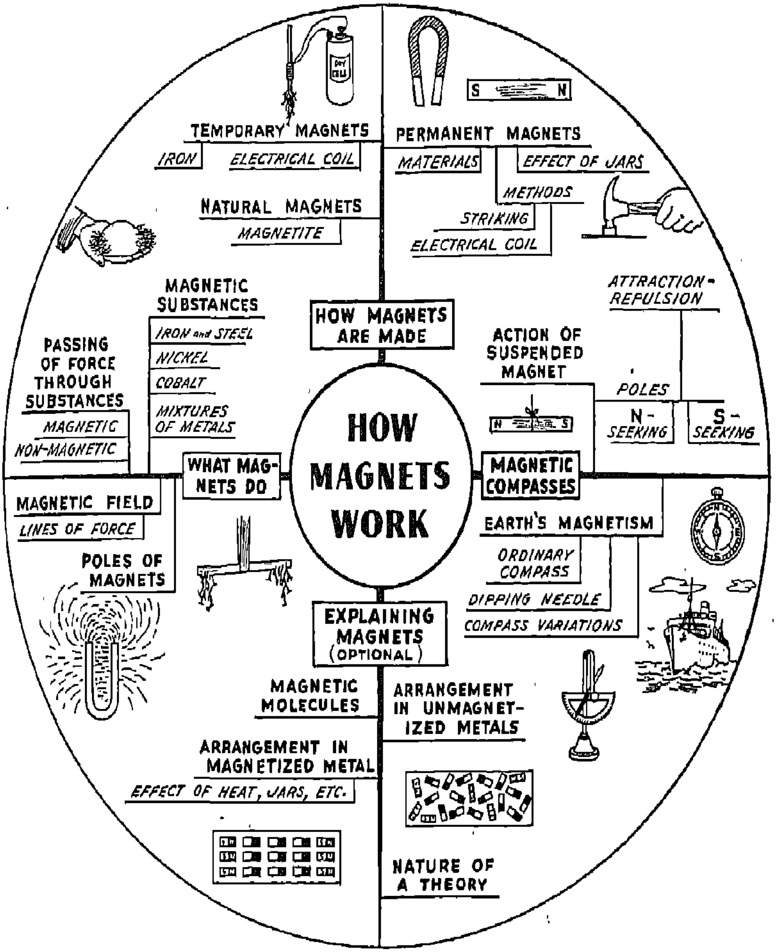

FIG. 10. GRAPH OF THE SUBJECT MATTER OF UNIT 7

It is different in that it loses its magnetic properties when the current of electricity is cut off. A permanent magnet keeps its magnetism unless subjected to some more or less violent treatment. e) To pick up piles of scrap iron; in compasses for finding directions; in various electrical devices for making and breaking contacts; to remove pieces of steel from the eye.

LOOKING AHEAD TO UNIT 7 (P. 229). Several interesting legends about the early history of magnetism make this preview material of decided value in introducing the unit to the pupils. This material provides a way of relating science with social studies and literature. The relationships between various fields, properly used, should serve to strengthen and make vital the total school experiences of the pupils.

A specimen of lodestone and several different-shaped magnets (Figure 162, page 230, of the text) that can be examined by pupils during the development of this part of the unit should stimulate a great deal of interest and bring forth many questions which can be used as guides to learning.

PROBLEM 1: WHAT WILL A MAGNET DO? (P. 231)

Magnetism is explained in this problem as a kind of invisible force that acts principally on certain substances. In addition to the usual *magnetic substances*, iron and steel, pure cobalt and pure nickel are presented as substances that magnets will attract. The idea of alloy magnets should be of interest, for in many cases the magnets being used by pupils will be of various magnetic alloys. If the names (usually trade names) of the kinds of alloy magnets being used can be obtained, a sense of reality will be given to the study.

As magnetic fields are being studied, be certain the pupils get the idea that the field of force extends in all directions about the magnet—not just in the single plane of the paper upon which the filings are sprinkled. If time and materials permit, let the pupils make blue-prints of magnetic fields; this will prove to be a very popular and stimulating activity.

The idea of "magnetic screens" will probably be entirely new material for most pupils and should be developed with care to avoid confusion.

The main ideas of Problem 1 are:

1. The few materials that are strongly attracted by magnets are known as magnetic substances.

a) Iron and steel are the most important magnetic substances.

b) There are other magnetic substances, such as pure nickel, pure cobalt, and various mixtures of metals.

2. Non-magnetic substances are those that are not attracted by magnets; there are more non-magnetic than magnetic substances.

3. Mixtures of some kinds of materials, such as aluminum, nickel, and cobalt, make the strongest (permanent) magnets.

4. Magnets have places called poles where the attracting force is strongest.

5. The space in which a magnet has power to attract is its field of force.

a) The field of force of a magnet extends out from the poles in all directions.

b) Small magnetic objects in a magnetic field tend to arrange themselves in lines that run in certain ways around the magnet; these lines are known as lines of force.

c) Lines of force are closest together where the magnetic force is strongest.

6. The field of force of a magnet will pass through all non-magnetic substances.

7. The field of force of a magnet will not pass through magnetic substances; the lines of force from one pole pass into the magnetic material and follow the material to the other pole, where they pass back into the magnet.

EXPERIMENT 27. WHAT WILL MAGNETS PICK UP? (P. 231). The apparatus and materials needed are: miscellaneous collection of magnetic and non-magnetic materials, piece of paper, steel magnet, and piece of lodestone.

SELF-TESTING EXERCISES (P. 233). 1. (*a*) By whether or not it attracts objects made of iron and steel; or (*b*) by testing it with a magnet to see whether it is attracted by the magnet.

2. Iron, steel, pure nickel, pure cobalt, and alnico (an alloy made of aluminum, nickel, and cobalt).

3. A magnet is an object made of iron, steel, or a mixture of aluminum, nickel, and cobalt that attracts certain substances, such as iron, steel, pure cobalt, and pure nickel with special force.

4. The list of objects is to be divided into columns as follows:

Attracted by Magnets		*Not Attracted by Magnets*	
iron rings	compass needle	pencil leads	glass marble
iron filings	steel needle	bits of paper	rubber band
steel marble	iron nail	strip of copper	piece of wood

PROBLEMS TO SOLVE (P. 233). 1. Some common pins are made of iron or steel, which is attracted by a magnet, and others of brass, which is not attracted by magnets. All are plated with a bright metal that makes them look alike.

2. It was probably copper, tin, or some other metal that is not attracted by a magnet.

3. This story could not be true because most money is made of gold, silver, copper, and other metals not attracted by magnets. Even nickels have too high a proportion of copper in them to be magnetic.

4. It is not pure tin, but a thin sheet of steel or iron coated with a thin layer of tin. The iron or steel part is attracted to a magnet.

5. Yes. Place a magnet on a piece of wood and float it in water. Bring a piece of iron near it, and the magnet will move toward the iron.

7. He must have stuck a steel needle or a piece of iron or steel in some form into the cork. This made the cork move around in response to the magnet.

EXPERIMENT 28. WHAT PARTS OF A MAGNET HAVE THE GREATEST PULLING POWER? (P. 235). The apparatus and materials needed are: *Part* a. Iron carpet tacks, a bar magnet, sheet of paper. *Part* b. Iron carpet tacks, horseshoe magnet, sheet of paper. *Part* c. Iron carpet tacks, lodestone, sheet of paper.

a) Most of the tacks cling to the ends of the magnet.

b) Most of the tacks cling to the ends of the magnet. Since the ends of a horseshoe magnet are closer together, the tacks may form "chains" between the ends. The ends of the bar magnet are too far apart for this to happen.

c) Lodestone has its magnetic force located at opposite sides or ends. Lodestone has stronger places just as other magnets do.

EXPERIMENT 29. WHAT IS THE FIELD OF FORCE OF A MAGNET? (P. 236). The apparatus and materials are: *Part a.* Bar magnet, horseshoe magnet, sheet of stiff paper, iron filings. *Part b.* Piece of lodestone, stiff paper, iron filings.

a) Iron filings arrange themselves into a pattern with lines of filings extending from one pole to the other. (NOTE: The magnet will not be strong enough to make closed curves of all the lines of force.)

b) The patterns of iron filings about the magnets are similar in that lines of filings extend from one pole to the other of the magnets. Of course, the shapes of the patterns are not alike because the shapes of the magnets are different. The lines are closest together at the poles of the magnets.

SELF-TESTING EXERCISES (P. 237). 1. Lines of force go out in all directions from the poles of a magnet.

Tacks, etc., cling to all sides of the poles of the horseshoe magnet in Figure 166. Figure 169 shows iron filings standing on end, showing that lines of force come from a magnet in this direction as well as out from the sides and ends, as shown in Figures 167 and 168.

2. That there are two places on the magnet where the force is strongest.

3. The pictures should be similar to Figures 167 and 168.

PROBLEMS TO SOLVE (P. 237). 1. Yes. The force of a magnet passes through air and through non-magnetic substances, such as paper, glass, cloth.

2. Experiments on making blue-prints of magnetic fields.

3. Yes. Experiments 28 and 29 showed that tacks and filings were attracted more strongly to certain parts of a lodestone.

EXPERIMENT 30. CAN A MAGNET ATTRACT IRON THROUGH SUBSTANCES? (P. 238). The apparatus and materials are: *Part a.* Bar magnet, iron filings, sheet of stiff paper. *Part b.* Same as for part a, plus thin sheets of zinc, copper, brass, aluminum, and wood. *Part c.* Same as for part a, plus a thin sheet of iron.

a) Filings are attracted through paper. Filings are attracted when the magnet is not touching the paper. When the magnet is moved, the filings follow it.

b) The answers for glass, sheets of zinc, copper, brass, and aluminum, and wood are same as for part a.

c) A magnet does not attract filings through sheet iron. Magnetic substances do not allow the lines of force of a magnetic field to go through them and out on the opposite side.

SELF-TESTING EXERCISES (P. 240). 1. Through non-magnetic substances, such as glass, zinc, copper, brass, aluminum, thin wood, and other things.

Can show that this is true by putting pieces of non-magnetic material over a magnet and sprinkling iron filings on it. Iron filings will arrange themselves along lines of force from magnet just as if no material were between them and magnet.

2. Through magnetic materials.

Can be shown by performing same experiment as for exercise 1, using a sheet of magnetic instead of non-magnetic material. Iron filings will not arrange themselves along any lines of force.

3. By surrounding an object with a case or a protecting screen of some magnetic substance.

Could protect delicate steel springs of some mechanism, like a watch, from being harmed by the pull of a strong magnet by having a steel or iron case made for it.

PROBLEMS TO SOLVE (P. 240). 1. No. Some of the lines of force go into the keeper instead of into the air around the magnet. Thus the field around the magnet is not so strong.

2. Experiment for pupils.

3. Covers of iron, steel, or some other magnetic substance are to prevent the magnetic force of near-by objects from reaching the tubes and disturbing them.

PROBLEM 2: HOW CAN WE MAKE MAGNETS? (P. 241)

Two methods of inducing magnetism in iron and steel objects introduce this problem: (1) Magnetizing by contact with another magnet and (2) magnetizing by means of an electric current. Both temporary and permanent magnets may be produced by these methods, depending upon whether iron or steel is to be magnetized. The use of iron produces temporary magnets, and the use of steel produces permanent magnets. Care of magnets, that is, not heating or jarring them, should be stressed when Experiment 32, page 243, and the material following it are presented.

The principles of electromagnets and their application to devices in common usage, such as electric motors and telephones, should make the material of this problem of practical value to the pupils.

The main ideas emphasized are:

1. Steel can be magnetized (*a*) by stroking it with a magnet, or (*b*) by passing a current of electricity through a coil of wire wrapped around it.
2. When steel is magnetized, a permanent magnet is produced. A permanent magnet holds its magnetism indefinitely.
3. Iron can be magnetized temporarily. Temporary magnets are magnets only when they are near a magnet or when they are surrounded by a coil of wire through which a current of electricity is flowing.
4. In order to keep their strength, magnets must be handled carefully; both jarring and heating weaken them.
5. A piece (core) of iron surrounded by a coil of wire carrying an electric current acts as a magnet and is called an electromagnet.
6. An electromagnet can be made stronger (*a*) by putting more turns of wire around the iron core, or (*b*) by sending more electricity through the wire.
7. Electromagnets are used in many common devices. They can be controlled by turning the electric current on or off.

EXPERIMENT 31. HOW CAN WE MAGNETIZE A PIECE OF STEEL? (P. 241). The apparatus and materials needed are: *Part a.* Large steel needle (or piece of clock spring), iron filings, piece of lodestone.

Part b. Needle (or clock spring), iron filings, bar magnet.

Part c. Spool of small cotton-covered or enamel-covered wire, cardboard tube of small diameter (one-half inch), unmagnetized knitting needle or other steel object, dry cell, hammer. (NOTE: Four dry cells connected in a series produce a stronger current and thus a stronger magnet. Ten seconds is usually long enough for the current to flow through the coil.)

a) The needle or piece of clock spring may attract a few iron filings before it has been stroked with a magnet because it has been accidentally magnetized in some way. When stroked with a magnet, such a needle will usually pick up many more filings.

b) Same answer as for part a.

c) The needle will usually attract tacks slightly, if at all, before it is placed in the coil and a current of electricity is sent through the coil. The needle becomes a permanent magnet.

EXPERIMENT 32. WHAT EFFECT DOES POUNDING HAVE UPON THE STRENGTH OF A MAGNET? (P. 243). The apparatus and materials needed are: Magnetized knitting needle, tacks, hammer, and board.

After the needle is pounded, it does not usually pick up nearly so many tacks as before it is pounded. When a magnet is pounded hard enough, it loses most of its magnetism.

SUPPLEMENTARY EXPERIMENT FOR EXPERIMENT 32 (P. 243). The apparatus and materials for this are: Magnetized knitting needle, pliers, Bunsen burner (or other source of intense heat), tacks.

Grasp a magnetized knitting needle with a pair of pliers and hold one end of the needle in the flame of a Bunsen burner until it is red hot. Then move the needle through the flame progressively from one end to the other until the entire length of the needle has been heated. Testing with tacks will show that the needle has lost most of its magnetism.

SELF-TESTING EXERCISES (P. 243). 1. (a) By stroking it in the same direction with the pole of a magnet; or (*b*) by passing an electric current through a wire wrapped around it.

2. Because it holds its magnetism for a long time.

3. A permanent magnet keeps its magnetism for a long time, while a temporary magnet loses its magnetic powers very rapidly, as iron in an electromagnet does when the current is turned off.

PROBLEMS TO SOLVE (P. 243). 1. Head of hammer has been magnetized.

2. Steel, because it is a permanent magnet.

3. Magnetize them and test them to see which one held its magnetism longer.

EXPERIMENT 33. HOW CAN YOU MAKE AN ELECTROMAGNET? (P. 244). The apparatus and materials needed are: *Part a.* Large nail, box of carpet tacks, about two feet of insulated copper wire, dry cell.

Part b. Same as for part *a*, with addition of another dry cell.

a) When wire is wrapped around a nail and the current of electricity is sent through the coil, the nail attracts tacks. When the coil is disconnected, the nail loses most of its magnetism.

b) When the number of turns of wire is increased, more tacks are picked up. Still more tacks are picked up when two dry cells are used. An electromagnet may be strengthened by increasing the number of turns of wire and by sending more electricity through the coil.

SELF-TESTING EXERCISES (P. 246). 1. By winding a bar (or core) of soft iron with many turns of insulated wire and passing an electric current through wire.

2. By increasing (a) the number of turns of wire around the iron core or (*b*) the electric current passing through the wire.

3. Because they do not retain their magnetism so long as steel. As soon as the current is shut off, they lose their magnetism. Use of magnetic force can thus be controlled more easily.

4. Temporary magnet.

PROBLEMS TO SOLVE (P. 246). 1. (a) Magnetic forces can be controlled so that a magnet can be turned on or off at will. (*b*) Strength of a magnet can be increased if desired, so that great loads can be picked up. (c) Easily and quickly made wherever electric current is available.

2. (a) Dependent on electric current to make them work, and are, therefore, only temporary magnets. (*b*) If current should be turned off in middle of operation, difficulties might result.

3. To pick up nails, bolts, screws, etc., that might cause punctures in tires.

4. Magnet would retain a great deal of magnetism after the current was shut off, since steel retains its magnetism much longer than the soft iron usually used in electromagnets.

5. Could have a piece of iron under each number and small electromagnets under the pieces of iron. The magician could secretly turn on a switch and press the button of the electromagnet under the desired number.

PROBLEM 3: WHY DO MAGNETIC COMPASSES TELL DIRECTION? (P. 246)

Most children have played with a compass and have enjoyed the experience. This interest can be used to introduce the problem, and the actual use of a compass for finding direction should be employed. Drawing upon experiences of Boy and Girl Scouts will undoubtedly prove to be of value in helping the class learn to find directions.

The proper way of preparing magnets for storage should be shown, since one aim of most school curricula is to get pupils to learn to assume their share of responsibility in caring for property. First, magnets should be wiped off with a cloth that has a few drops of machine oil on it to keep the magnets from rusting. Second, magnets should be stored in a strong wooden or cardboard box with the unlike poles lying next to each other. Third, a thin strip of wood or cardboard should keep the magnets from touching each other. Fourth, pieces of sheet iron should be placed across the poles of the magnets. (These pieces of iron can be cut from a "tin" can, which is really sheet iron dipped in tin.)

The main ideas of the problem are:

1. A magnet has two poles.

a) The pole that points north when the magnet is free to turn is called the north-seeking pole.

b) The pole that points south is called the south-seeking pole

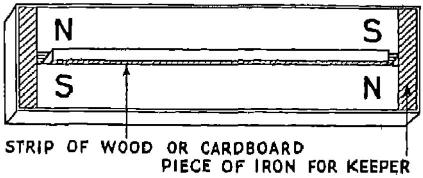

FIG. 11. STORAGE OF MAGNETS

2. The laws of polarity of magnets are as follows:

a) Like magnetic poles repel each other.

b) Unlike poles attract each other.

3. A small magnetized needle suspended from its center shows the direction of the lines of force in a magnetic field.

4. A magnetic needle that is free to swing in a horizontal plane is known as a compass.

5. A magnetic needle that is free to swing in a vertical plane is known as a dipping needle.

6. The earth behaves like a huge magnet.

7. The magnetic poles of the earth are not located at the geographic poles. Therefore, there are many places where a compass does not point to the true north and south direction.

8. The magnetic poles of the earth slowly change their positions.

EXPERIMENT 34. WHAT HAPPENS TO A MAGNET WHEN IT IS HUNG ON A THREAD OR STRING? (P. 247). The apparatus and materials are: *Part* a. Wooden support for magnet (have pupils make it if possible), bar magnet, thread.

Part b. Same as for part a, but using another bar magnet.

a) Magnet points approximately north and south (variation depending upon location).

b) Same results as with part a of experiment.

EXPERIMENT 35. HOW DO THE POLES OF A MAGNET ACT TOWARD EACH OTHER? (P. 248). The apparatus and materials are: Magnet support used in Experiment 34, two bar magnets.

a) North poles of magnets repel each other.

b) North pole of suspended magnet and south pole of other magnet attract each other.

c) Results same as parts a and *b* of experiment.

EXPERIMENT 36. HOW DOES A MAGNETIZED NEEDLE ACT WHEN IT IS NEAR A MAGNET? (P. 249). The apparatus and materials needed are: Bar magnet, thread, magnetized needle.

The south-seeking pole of a needle points downward when held over the north-seeking pole of a magnet. The north-seeking pole of a needle points downward when held over the south-seeking pole of a magnet. When a needle is suspended halfway between the north- and south-seeking poles of a magnet, the needle hangs parallel to the magnet because its north- and south-seeking poles are attracted with equal force by the south- and north-seeking poles, respectively, of the magnet.

The needle followed the lines of force around the magnet. The poles of a magnet can be located with a suspended needle when a piece of paper is placed over the magnet.

SELF-TESTING EXERCISES (P. 251). 1. A magnet hung so that it is free to turn in a circle. Since it will be attracted by the magnetic pole of the earth, it can be used to determine directions.

2. Set the compass so that the needle points north over the line marked N on compass card; then face left of that direction and go straight ahead.

3. Yes. Can be shown to be correct by an experiment with two bar magnets, arranged so that one is free to swing. This will show that like poles repel each other and unlike poles attract.

4. At the magnetic poles the needle points straight down, indicating that the poles are directly beneath the point where the dipping needle is.

5. Because the needle, or pointer, of a compass is a magnet with a north and south pole. These poles are attracted by the north and south magnetic poles of earth and thus point north and south.

6. So that they would not attract the magnets and thus hide the effect of the earth's magnetism.

Problems to Solve (p. 251). 1. No. Since the north-seeking pole of the magnet points in the direction of the north magnetic pole, it must be different, because only unlike poles attract each other.

2. No. Iron ore would attract the compass, since iron ore is often a magnetic substance and also a screen for the magnetic field of a compass and prevents it from being attracted by the magnetic pole of earth.

3. Suspend the magnetized clock spring by a thread. It would make a compass and would point almost north and south.

4. A dipping needle compass points downward at the poles of the earth just as the needle did in Experiment 36. At the equator the compass needle is level. In between the poles of the earth a compass needle points toward the poles as it did in Experiment 36.

5. An experiment for pupils.

6. A magnet was concealed on one side of the table. The compass needle pointed toward the magnet and moved as the table moved.

7. Bring a bar magnet close to each end to see if the two ends of the steel bar act differently toward the poles of the magnet. Or move the bar by tapping one end or turning the support. See if the bar points in the same direction as before.

Self-Testing Exercises (p. 254). 1. Because the magnetic north pole is not in the same place as the geographic north pole.

2. The south-seeking pole of the needle would point straight down because unlike poles attract each other.

4. That the geographic pole and the magnetic pole were in the same place.

Problems to Solve (p. 255). 1. No. The magnetic poles of the earth are slowly changing position.

2. Yes. Because if he followed his compass, he would not be going north, as he thought he was, unless he was on the line marked "No Variation" on his chart.

3. The box would form a magnetic screen so that the compass would not be affected by the earth's magnetism.

4. The south poles of the magnetized needles are attracted to the north pole of the magnet. When the other pole of the magnet is used, the north poles of the needles are attracted to the south pole of the magnet.

PROBLEM 4 (OPTIONAL): HOW IS MAGNETISM EXPLAINED? (P. 256)

The elements of the scientific method can be used to good advantage. Since pupils have learned what a theory is (page 102 of text), it should again be explained that no one has seen the molecules of a magnetic substance. However, pupils should be led to see that the theory is quite acceptable because it explains what is required of it in a satisfactory manner.

When pupils understand how magnetism is explained, they should make applications of this knowledge by explaining what they have learned earlier in the unit in terms of the molecular theory. For example, Experiments 31, 32, and 33, and the polarity of magnets can be interpreted satisfactorily by pupils when Problem 4 has been studied.

It should be pointed out that pupils may become confused by Problems 2 and 3 of *Problems to Solve* on page 259. Steel becomes a better magnet if the steel is pounded lightly while it is being magnetized in a strong magnetic field. The pounding helps the molecules to line up. When magnets are dropped, some of the molecules are likely to be jarred out of alignment, causing the magnets to lose some of their strength.

The main ideas developed in this problem are:

1. The theory of magnetism assumes (a) that each molecule of a magnetic substance is a tiny magnet, and (*b*) that each of these molecules has a north and a south pole.

2. The molecules of a magnetic but unmagnetized substance are believed to be arranged in a "hit-or-miss" fashion. In this condition the magnetic forces of all these molecules are believed to *neutralize* each other.

3. The molecules of a magnetized substance are believed to

be aligned so that their poles are all pointing in the same direction.

4. The theory of magnetism is confirmed by the following facts:

a) A magnet is weakened if it is jarred. (Molecules are shaken out of position.)

b) Heating a magnet destroys its magnetism. (Molecules can move around more easily and change their positions so that their poles will neutralize each other.)

c) Breaking a magnet in two produces two magnets. (South poles of molecules in both pieces are all pointing in the same direction. Same is true of north poles. Thus each piece has a north and a south pole.)

SELF-TESTING EXERCISES (P. 258). 1. Molecules in an unmagnetized bar are arranged in a haphazard fashion, in which they neutralize each other. Molecules in a magnetized bar are arranged so that the poles of the molecules are all in the same direction, and the little molecular magnets do not neutralize each other at the ends of the magnet.

2. (a) A magnet loses much of its magnetism if pounded. The molecules are shaken up and can again arrange themselves hit-or-miss. (*b*) A magnet loses some of its magnetism when it is heated. (c) If you break a magnet in two, opposite poles are found on each side of the break.

PROBLEMS TO SOLVE (P. 259). 1. No. If each of the molecules making up a magnetic substance is a small magnet, and the material is showing its magnetic qualities, the molecules are so arranged that there will be two poles. If a magnet is broken, two new poles are "exposed" at the break.

2. By pounding a magnet while it is in a strong magnetic field, one can assist molecules to line up so that the poles are pointing in the same direction.

3. A magnet should not be dropped, because jarring shakes the molecules out of position and thus lessens magnetism. Shaking up molecules changes the arrangement so that some of them neutralize each other.

4. Molecules are not so free to move in steel as in iron and are not so easily jarred out of place as in iron.

5. The needle becomes magnetized because the magnetic force or lines of force from the strong magnet pass into the needle and attract the molecules of the needle so that they change to a position with their poles all pointing in the same direction. This gives the needle its magnetic qualities.

LOOKING BACK AT UNIT 7 (P. 259). Reference to the unit graph will clarify the organization of the unit. (See p. 161.)

1. (a) Certain substances have magnetic qualities; that is, they are able to attract objects made of iron and steel, or they are themselves attracted by magnets.

b) The ends of magnets, called poles, are where magnets exert their greatest force.

c) The influence of a magnet reaches out through the space around it. This influence passes through non-magnetic substances, but space beyond magnetic substances is shielded from it.

d) A piece of iron or steel can be magnetized by stroking it with a magnet or by passing an electric current through a coil around it.

e) Some materials hold their magnetism longer than others.

f) Like poles of a magnet repel each other, and unlike poles attract each other.

g) The earth is a giant magnet, with its poles some distance from the geographic poles.

2. A compass is an instrument for finding directions by means of a free-swinging magnet which usually points in a general north-and-south direction because of the earth's magnetism.

A *dipping needle* is a special kind of compass with the magnet swung so that it can turn up and down rather than around in a horizontal direction. One end of such a needle will point straight down when the needle is directly over the magnetic pole of the earth.

An *electromagnet* is a temporary magnet made by passing an electric current through a coil around a piece of iron.

Lodestone is a type of rock that is magnetic. It is an iron compound.

The *magnetic field* is the space around a magnet in which the force of the magnet can be detected.

A *magnetic substance* is one that either has the power to attract certain substances to it or is itself attracted to a magnet.

Magnetism is a characteristic of certain substances that enables them to attract other substances.

A *non-magnetic substance* is one that is not attracted by a magnet.

A *permanent magnet* is one that keeps its magnetism for a long time, or more or less permanently.

The *pole of a magnet* is the region where the magnetic force is strongest.

The *south-seeking pole* is the pole of a magnet that is attracted by or points to the south magnetic pole of the earth.

A *temporary magnet* is one that does not keep its magnetism all the time but that can be magnetized at will by means of an electric current.

ADDITIONAL EXERCISES (P. 259). 1. There are probably a number of ways of doing this experiment. One rather satisfactory plan is to place the compass on a table and allow it to come to rest with the needle as nearly north and south as it will go. Place one magnet on an east-and-west line through the center of the compass and quite a distance away. Have the two poles of the magnet equally distant from the center of the compass. Bring the magnet toward the compass until the needle turns a certain distance (say 15°) from its resting position. Mark the position of the magnet. Then place the second magnet at the marked place with its N and S poles turned the same way as the first magnet. Notice whether the compass needle turns farther or less far than it did with the first magnet.

2. By increasing the number of coils around the piece of iron being made into a magnet or by increasing the strength of the electric current sent through the wire.

3. By seeing which of the needles attracted another needle. An unmagnetized needle would not attract any magnetic substance to it.

4. Suspend the magnetized needle by a fine thread and approach poles with a bar magnet having the poles marked. Each pole of the needle will be the opposite of the pole of magnet that attracts it.

5. (a) Since like poles of needles are close together at first, these poles repel each other, and corks move apart.

b) Same as (a).

c) Since unlike poles are close together, they attract each other, and needles move closer together.

6. (a) Attraction between poles shows up as continuous lines of force between poles. (See Fig. 186.)

b) Same as (a).

c) The lines of force from like poles act against each other. (See Fig. 186.)

7. If the magnet on top is light enough, repulsion of it by the other magnet will raise the top magnet into the air.

8. Magnets will pick up more tacks when unlike poles are held close together but not touching.

9. The gun would attract the compass needle. Should have gun as far away as possible. Can check by moving the compass or gun to see if there is any effect on the needle.

10. Telephone, doorbell, telegraph set, electric motors, etc.

11. Brass is not a magnetic substance. However, thin nickel coating of pin is a magnetic substance. Bringing a magnet near the pin will cause the pin to turn slightly because a magnet attracts nickel coating.

BULLETINS AND PAMPHLETS FOR UNIT 7

Coast and Geodetic Special Publication
No. 117. *Earth's Magnetism.* 15c

VISUAL MATERIALS FOR UNIT 7

Society for Visual Education (filmstrip)
"Magnetism"

UNIT 8

How Are Plants and Animals Alike?

FUNCTION AND SCOPE OF UNIT 8. This is the opening unit of the series dealing with the biological aspects of our environment. An interpretation of the activities of and processes in plants and animals cannot be adequately made until pupils have an idea of the organization of living things. This unit is planned to introduce pupils to some of the main ideas about the activities and organization of both plants and animals.

Although some of the ideas from preceding units are reviewed briefly where they are needed in the present unit, pupils will make much better progress if they have gained the following from Units 5 and 6: (*a*) Knowledge of what an element is and familiarity with some common elements, especially carbon, hydrogen, oxygen, and nitrogen; (*b*) knowledge of what a compound is and familiarity with some common compounds, especially water and carbon dioxide.

Grasp of the main ideas of this unit is essential for the most rapid progress in Units 9 and 10 of this book. Refer to the graph on page 180.

INTRODUCTORY EXERCISES (P. 264). 1. Both have definite shape; both have weight; and both take up space.

2. Squirrel is alive; stone is non-living. Made of different materials.

3. Oak tree is a plant; squirrel is an animal. Oak tree makes its own food; squirrel has to get it from plants. Oak tree is fastened to one spot; squirrel can move around.

4. Both are living things. They respond to stimuli and carry on activities necessary for living things, namely, reproduction, growth, getting food, water, air, etc.

5. (a) Obtain food and water; (*b*) obtain oxygen; (c) give out wastes; (*d*) grow; (e) move all or parts of their bodies; (*f*) produce more of their own kind; (g) respond to stimuli; (*h*) protect themselves or be protected from their enemies; (*i*) be adapted to their physical surroundings.

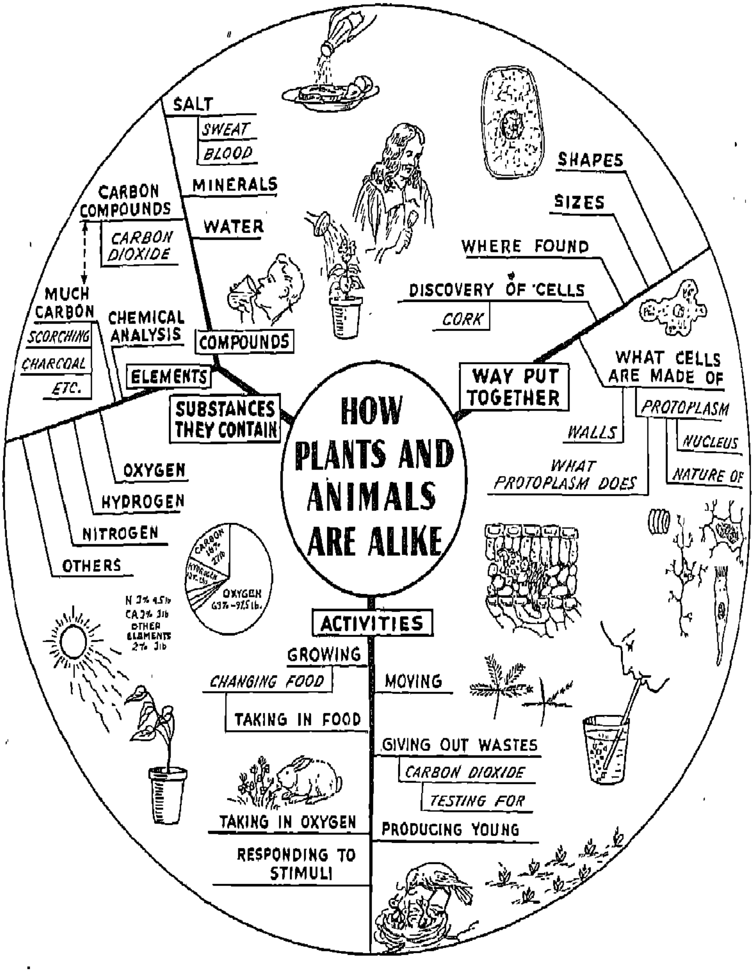

FIG. 12. GRAPH OF THE SUBJECT MATTER OF UNIT 8

6. Small units of living material that make up both plants and animals.

In the cells is the protoplasm, or living material, that carries on all the life activities, and the nucleus, a very important part of the protoplasm, that not only controls the activity of the other parts of the protoplasm but controls the heredity of the plant or animal.

LEGEND UNDER FIGURE 188 (P. 265). *Animals:* starfish and sea-anemone. *Plants:* puff balls and diatoms.

LOOKING AHEAD TO UNIT 8 (P. 265). To introduce pupils to this unit it will be satisfactory for the teacher either to have pupils read the section "Looking Ahead to Unit 8" or to give a brief talk. The talk may well grow out of pupils' responses to questions about the differences between plants and animals and about their similarities. Be sure to make full use of Figures 188, 189, and 190. Any evaluation of the results of the introduction should seek to determine whether the pupils have the following ideas:

a) Not all plants and animals look like the ones we are familiar with; some are so like both plants and animals that scientists do not know which they are.

b) Plants and animals are alike in many ways. How can they be alike?

PROBLEM 1: HOW ARE PLANTS AND ANIMALS ALIKE IN WHAT THEY DO? (P. 268)

The purpose of this problem is to show that all living things are alike in the kinds of activities they must carry on to remain alive. It is especially important to stress the fact that plants, too, are alive. Following are the main ideas of the problem:

1. Animals and plants are alike in that they (*a*) move all or some parts of their bodies, (*b*) use food, (*c*) use oxygen, (*d*) give out waste materials, (*e*) produce young, (*f*) grow, and (*g*) respond to stimuli.

2. Messages received by the body of an animal that result in activity are called stimuli.

3. The way an animal acts when it receives a stimulus is called a response.

4. Living things grow from the inside; food is changed to living material that is added to the body.

EXPERIMENT 37. HOW DO CRYSTALS GROW? (P. 270). The apparatus and materials needed are: about four ounces of crystals of alum, copper sulphate, or sodium hyposulphate (photographers' "hypo"), one-fourth pint warm water, glass (or beaker), very fine thread.

The directions for this experiment are sufficiently detailed to ensure success. Pupils who become interested may grow large crystals of more perfect shape by placing small crystals on the bottom of a dish of saturated solution. Each crystal should be turned over with a glass rod or other non-metallic device each day or two. Those that grow symmetrically should be transferred to a new saturated solution occasionally.

EXPERIMENT 38. DO PLANTS GIVE OUT CARBON DIOXIDE AS ANIMALS DO? (P. 273). The apparatus and materials are:

Part a

Two test-tubes
Stopper, 1-hole, to fit test-tube
Glass tubing, right angle, to fit in stopper
Rubber tubing to fit snugly over glass tubing
Test-tube rack (or other arrangement) to hold tubes upright
Small pieces limestone (or marble)
Dilute sulphuric acid
Limewater

Part b

Two large glass (or stone) jars
Two covers to fit jars
Small potted plant
Two small beakers (or drinking glasses)
Pot of moist soil same size as one containing plant
Limewater

See directions for diluting sulphuric acid in Experiment 25, page 152. See directions for making limewater in Experiment 20, page 141. (Be sure the limewater is clear and not too old.)

a) This part of the experiment shows the chemical test for carbon dioxide.

The reaction that takes place when dilute sulphuric acid is added to limestone is:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2 \uparrow$$

The reaction that takes place when the carbon dioxide is bubbled into the limewater is:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$$

(NOTE: In the equations above an arrow pointing upward [↑] indicates the evolution of a gas; an arrow pointing downward [↓] indicates the formation of a precipitate.)

The calcium carbonate is insoluble in water and forms a fine powder that produces the milky-white appearance. (Calcium carbonate provides a ready means of preparing carbon dioxide for commercial use.)

b) Yes. The change in the colorless solution to a milky-white shows that carbon dioxide has been added to the solution. No other gas known to scientists will do this with limewater. (See text, p. 193.) (Limewater is a clear, saturated solution of calcium hydroxide, a white powder, in water.)

c) The jars should be kept in a dark place to prevent photosynthesis, in which carbon dioxide may be taken out of the air. Since there is carbon dioxide in the air, some white material may be produced in the jar without a plant. Comparison of the limewater in the two jars, however, will show more white material in the jar containing the plant.

SELF-TESTING EXERCISES (P. 276). 1. Pupils are to give original examples. The table on page 184 gives sample responses.

ACTIVITIES OF LIVING THINGS	ANIMAL EXAMPLES	PLANT EXAMPLES
Producing young	Turtles lay eggs from which young turtles hatch.	Young potato plants grow from potatoes put into ground.
Growing	Puppy grows into a dog.	Small tree seedling becomes large tree.
Using food	Cat catches mouse and eats it.	Fact that plants take in water, minerals, etc., from soil to help make food shows that they need food.
Using oxygen	Many animals have special organs, the lungs, for taking oxygen into body.	A house plant dies because excess water in pot with no drainage shuts off air from roots.
Moving all or parts of body	Horse runs from one place to another by means of legs	Parts of a bud turn back as the bud opens.
Responding to stimuli	You can touch a hot radiator and quickly pull your hand away.	Roots of plants grow toward loose parts in drain tiles where water is escaping.
Giving out wastes	Animals breathe out carbon dioxide.	In some kinds of soil waste materials from roots are harmful to growth of a certain kind of plant.

2. A message that causes a living thing to do something, or respond. Sample examples are: (a) Automobile horn makes you jump quickly out of the way. (b) You smell food, and your mouth waters. (c) Dog hears someone coming and starts to bark.

3. Some non-living things can move about, take in oxygen, give out water, get larger, use fuel (or food), and respond to stimuli, but not in the same way that animals or plants can. They do not reproduce more of their kind. All living things do all of these things, but no non-living thing can do all of them.

PROBLEMS TO SOLVE (P. 276). 1. Sample response: A dog and a locomotive are alike in that each (a) needs energy to carry on activities, (b) needs fuel to supply the energy, (c) needs oxygen to get the energy from the fuel, (d) wears out and needs repair, (e) produces waste material, (f) has parts that move.

Because a locomotive cannot do these things in the same ways a living thing does them and because a locomotive cannot do *all* the important things a living thing does.

2. Pupils will probably need some suggestions for making significant observations.

a) Look at an opening flower bud from time to time.

b) Set a stake beside a growing plant with a pin or firmly fastened wire arranged so that the end of the pin or wire marks a leaf tip or stem tip of the upper part of the plant. Observe at intervals to see if the plant shows movement. A vine, such as a morning-glory or a pea vine, is especially good.

c) Use a potted plant that has been subjected to one-sided illumination (as in a window). Arrange to have the light come from a different direction, or turn the plant around. Then mark certain leaves as in *b* and observe from time to time.

3. The following are possibilties. If possible, get the pupils to plan their own experiments. If they do, they may well be much different from the examples given.

a) One possible experiment to observe response to light is given in 2c above. Young oat or radish seedlings germinated in a dark place are especially good. Results with seedlings are best if they are placed at the back of a box that has a small hole in the front through which light may shine.

b) For the second experiment peas or beans may be germinated in moist towel paper in a covered dish. Then pin the seedlings to a board in several positions and place the board in a saturated atmosphere (covered jar with water in the bottom).

5. This problem should involve some reading in biology books. If undertaken as an original effort, the pupils should be cautioned to specify that they are writing about the kinds of plants and animals with which they themselves are familiar and that what they say may not be true of plants and animals unknown to them.

PROBLEM 2: WHAT CHEMICAL SUBSTANCES ARE LIVING THINGS MADE OF? (P. 277)

This problem shows that plants and animals are alike in chemical composition and that the substances of which their bodies are composed are also found in non-living things. The main ideas developed are stated on page 186.

1. Bodies of living things are made of chemical elements.

a) Most of the human body is made of six elements: oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus.

b) Most of the calcium and phosphorus are found in the bones.

c) Oxygen, carbon, hydrogen, and nitrogen are the elements involved in almost all of the chemical changes in living things.

d) Only very small amounts of some elements are required, but they are necessary for life.

e) The elements of which plants are made are the same as those of which animals are made.

f) Living things differ from non-living materials in that they contain a much higher proportion of carbon.

2. Different compounds have different uses in the bodies of plants and animals.

a) Water makes up about two-thirds of the body weight and is used as part of the blood, as part of the perspiration, and for carrying away wastes.

b) Salt is used to make hydrochloric acid necessary for digestion.

c) Calcium phosphate is used to make bones.

d) Plants and animals contain thousands of different carbon compounds, each of which has some use.

SELF-TESTING EXERCISES (P. 283). 1. Oxygen, carbon, hydrogen, and nitrogen.

2. Carbon. (a) It exists in many very different forms. (*b*) It makes up only a small part of the non-living world, but about 18% of living things are carbon. (c) It is found in about ten times as many different compounds as all the other elements put together.

3. Water. Hydrogen and oxygen.

4. Carbon dioxide. Carbon and oxygen.

5. Bones and teeth.

6. (a) Most of their weight is made up of water. (*b*) The rest of their bodies are made up of the same elements. (c) The most important elements for both plants and animals are carbon, oxygen, hydrogen, and nitrogen. (*d*) They both make and use a great many carbon compounds.

PROBLEMS TO SOLVE (P. 283). 1. (*a*) Compounds of carbon and other compounds found in living things are different from those in non-living things. (*b*) Chemical compounds in living things are usually much more complex than those in non-living things. (*c*) Proportion of carbon to other elements is much greater in living things.

2. Select vigorous young plant. Weigh and record weight. Allow plant to dry in air, or, if possible, in oven that can be set low enough to dry plant but not burn it (about 100° C). Weigh at intervals until weight remains same for several weighings.

Subtract dry weight from original weight. This gives amount of water lost by weight, or, roughly, amount of water in plant. Divide this amount by total or original weight to determine percentage of water present in plant at beginning of experiment, or percentage of total weight of plant that is water.

3. Research project. An example of such information is a chart in *Compton's Pictured Encyclopedia,* under the article on "Earth." (This is a circle graph.)

4. Oxygen. (*a*) Colorless, odorless, a gas. (*b*) Necessary material for burning. (*c*) Makes up about one-fifth of composition of air. (*d*) Somewhat heavier than air. (*e*) Oxidizes or combines with nearly all other materials to form compounds.

PROBLEM 3: HOW ARE PLANTS LIKE ANIMALS IN THE WAY THEY ARE PUT TOGETHER? (P. 284)

This problem stresses the cell structure of living things. It presents the basic concepts necessary for an understanding of how living things carry on the activities of living. If it is at all possible, pupils should observe cells under a compound microscope. There is no adequate substitute for the actual seeing of the cells and the way they fit together, yet observations with a good magnifier should not be neglected (Experiment 39a).

Following are the main ideas developed in the problem:

1. All living things are made of cells.

a) The cells make up the body much as bricks or stones make up the walls of a building.

b) The work of the body is done by the cells.

2. Cells are made of several parts.

a) Inside the cells is protoplasm, a clear, syrup-like material.

b) A denser, rounded piece of protoplasm in the cell is the nucleus, without which most cells cannot live.

c) Plant cells have stiff cell walls, but most animal cells do not have walls.

3. Cells are of many different shapes and sizes.

4. Each large living thing has many different kinds of cells.

a) Each different kind of cell has a special kind of work to do.

b) The cells that make up the bodies of living things work together for the benefit of the whole body.

5. The protoplasm of cells carries on the work of the body.

a) It takes in food.
b) It makes chemicals from the food.
c) It uses food for growth and self-repair.
d) It takes in and uses oxygen.
e) It gives out waste materials.
f) It reproduces.
g) It responds to stimuli.

EXPERIMENT 39. WHAT DO PLANTS AND ANIMALS LOOK LIKE UNDER THE MICROSCOPE? (P. 284). Apparatus and materials are:

Part a	*Part b*	*Part c*
Magnifier (preferably six power or higher) Sharp knife (or safety-razor blade) Pieces of glass (preferably microscope slides) Plants with cells easily seen (cork, tomato, apple, celery stalk) Water Medicine dropper (desirable)	Compound microscope The materials from part a Small water plants Microscope cover glasses, if possible	Compound microscope Prepared slides of animal tissue (epidermis of frog, brain or spinal cord, large intestine, blood, etc.) Clean toothpicks or matches Small knife Medicine dropper Water Fountain-pen ink Cover glasses

The cellular structure of simple water plants and of some moss leaves may be demonstrated readily by mounting them whole in water on an ordinary microscope slide with a cover glass. Narrow portions of leaf epidermis may be obtained in many cases by doubling the leaf back and tearing it obliquely in such a way that the epidermis is separated from the underlying tissues.

Properly used, a reasonably good magnifier will make the cells in many plants visible. To see best, the eye should be placed quite close to the magnifier lens. A desirable type of simple microscope has a support for lens, specimens, and a mirror, so that the teacher or a careful pupil can arrange the material and let it remain in one position while the members of the class examine it, one by one.

Cells may easily be obtained from the lining of the mouth by scraping the inside of the lip or cheek with a clean toothpick or match stick. The mucus thus obtained should be scraped from the wood on to a dry slide with a small knife and spread out. It will then adhere while a few drops of stain (fountain-pen ink or other dye solution) are applied and later washed off with water. It will usually be found to contain large numbers of flat cells in which the nuclei can be seen easily. Staining is not essential. If it is not convenient to use the stain, add a drop of water and cover glass. The cells will appear as colorless polygons with a circular nucleus in each.

EXPERIMENT 40. WHAT ARE THE PARTS OF CELLS? (P. 287). The apparatus and materials needed are:

Part a

Amoeba culture
Glass microscope slide
Cover glasses
Medicine dropper
or Prepared microscope slide of amoeba in place of these
Compound microscope

Part b

Onion
Tweezers
Glass microscope slide
Cover glasses
Compound microscope
Water

a) It is usually very difficult for pupils untrained in the use of the microscope to find amoebas and hold them in focus. For this reason it is often desirable for the teacher to demonstrate the amoeba, using a single microscope. Unless the teacher has had experience in culturing and locating amoebas, it will be better to purchase a culture from a biological supply company or to use a prepared slide. In case a culture is purchased, a clean medicine dropper should be used to obtain a drop of the sediment from the bottom of the container. Such a drop, placed on a slide and covered with a cover glass, will usually contain one or more amoebas.

Prepared slides obtained from a laboratory supply house, while not so good as live material, may be substituted for live material. The teacher should explain with care that the animals are dyed, or stained, to make them more easily visible, since this may be the first experience that pupils have had with a microscope. The tremendous magnification should be stressed; otherwise, pupils may obtain an erroneous idea of the size of the objects. On prepared slides the amoebas are just barely visible without a magnifier or microscope. The pupils should be encouraged to look for them with their unaided eyes.

b) To obtain onion epidermis for slides, remove the outer dried scales of the onion and cut a quarter section from the inner layers of the onion. Double a single layer of the section away from the inner epidermis and toward the outer. The layer will usually break across, leaving only the outer epidermis unbroken. This may then be peeled off in strips from which small pieces may be cut with scissors for examination under the microscope. Be sure to spread out each piece so that a single layer of cells may be examined. Some of the cells of tissue prepared in the manner described usually exhibit a very large brownish or yellow nucleus in each. Some pupil might draw a section of the onion skin on the board to show how the cells fit together.

SELF-TESTING EXERCISES (P. 292). 1. The paragraph should include several or all of the points listed on the next page.

a) Cells are the small "pieces" (or hollow spaces with or without walls around them) of which plants and animals are composed.
b) Cells are of many shapes and sizes to do different things.
c) Cells do everything that plants and animals do.
d) Cells, when alive, contain protoplasm in which there is a nucleus; it is really the protoplasm that is alive and does things.

2. Protoplasm is the clear, syrup-like living material inside cell walls or membrane.

Protoplasm takes in food, uses food to make more protoplasm for growth and self-repair, makes all the chemicals the body needs from these foods, reproduces, uses oxygen, gives out waste materials, and responds to stimuli.

3. Living cells can do everything that protoplasm can do. Cells can grow larger; they can divide to form more cells of the same kind or that grow into other kinds of cells; they do many different things in different parts of the bodies of plants and animals.

4. Size, shape, and work they do, whether or not there is a wall, kind of wall.

5. Each pupil should state several of the following points:
a) Different individuals do different things, one group doing a particular kind of job for all the rest.
b) Individuals are dependent on others.
c) Individuals coöperate with each other for the good of the group as a whole.
d) Individuals are alive and need food and oxygen.
e) Individuals are often injured or become diseased.
f) Individuals are able to produce other individuals.

6. (a) Both are made up of cells.
b) Both are made of protoplasm that carries on life activities.
c) Both have many different kinds of cells.

Problems to Solve (p. 292). 1. Uses oxygen, takes in food, grows, gives off waste materials, makes more of its own kind, responds to stimuli, and moves.

It must do these things because it is a living thing, and these are the characteristics of a living thing.

2. The interpretation of this problem may vary. If it is taken to mean different kinds of cells within each individual, the answer is that there are different kinds of work to be carried on, such as

carrying messages, contracting, and protecting other parts. Each kind of work can be done best by a cell that is fitted for that work.

If the problem is taken to mean a contrast between plants and animals, the answer is that because plants and animals, of the kinds that are most familiar, carry on their lives in different ways, they have different parts with different duties to perform.

If it is taken to mean different from one animal to another and from one plant to another, the answer is much the same as for *b*.

3. It can make new protoplasm (p. 291). (*Another way of stating the same thing is:* It can cause plants and animals to grow by taking in materials and changing them into more of itself.) Chemists can put together the chemicals in protoplasm, but they cannot make protoplasm.

4. Carbon, hydrogen, oxygen, nitrogen.

5. (*a*) See if they take in food. (*b*) See if they respond to stimuli. (*c*) See if they make more of their kind in any way similar to plants and animals. (*d*) See if they use oxygen.

If after trying your experiments you find that the icicle-like bodies do not do all of these things, you can be sure that they are not living things as we understand the term "living things."

LOOKING BACK AT UNIT 8 (P. 293). It may be helpful to copy on the board the unit graph from page 180, which may be used in working out exercise 1.

1. The nature of satisfactory answers should be clear from text material. See the lists of main ideas, pages 181-182, 186, 187-188.

2. *Protoplasm* is the living stuff, similar to egg white, that is present in each living cell and does the work of living.

Carbon is one of the chemical elements most commonly seen in the form of soot and charcoal and graphite. Carbon is an essential element and is abundant in plants and animals.

Carbon dioxide is a compound of carbon and oxygen given off by fires when carbon burns and by living things.

Chemical analysis is the making of tests (and measurements) of any material to find out what elements and compounds (and how much of each) are in it.

A *cell* is one of the tiny pieces of which all living things are composed.

A *nucleus* is a rounded dense mass of protoplasm, usually one in each cell, without which the cell cannot continue living.

Oxygen, a gaseous chemical element found in the air, is necessary to cause burning and is used by practically all plants and animals in the process of living.

A *stimulus* is anything to which a plant or animal will respond. Examples of stimuli are light, sounds, odors, etc.

ADDITIONAL EXERCISES (P. 293). 1. Yes. The tree has manufactured food, and the fungus takes its food from different parts of the tree.

2. (NOTE: To keep the paper moist for the bean, put it in a covered dish, jar, or pan.) Both have started to grow into a new plant or animal. Cells in each have grown and divided to make more cells. To do this both had to use food for energy. Both had to have oxygen in order to use the food. Cells of both are giving off waste products as they use food and grow.

3. Moisture. Came from the plant, mostly from the leaves (through the pores, or stomata).

4. Animals. Animals have a brain and a nervous system that make the whole body and parts of the body responsive to stimuli. The special sense organs of the body make it receptive to more kinds of stimuli.

BULLETINS AND PAMPHLETS FOR UNIT 8

Bausch & Lomb Optical Company
    The Use and Care of the Microscope

VISUAL MATERIALS FOR UNIT 8

MOTION PICTURES

Eastman Classroom Films
    "The Living Cell"
    "Wild Flowers"
    "Microscopic Animal Life"

SLIDES AND FILMSTRIPS

Keystone View Company
    Unit No. 7:, Living Things—Plants (20 slides)
Society for Visual Education (filmstrip)
    "Animal Parade, from Sea Anemone to Man"

UNIT 9

How Do Plants and Animals Get Food?

FUNCTION AND SCOPE OF UNIT 9. This unit serves two purposes in the intellectual growth of boys and girls: (1) In case they have not previously been introduced to food-getting, they will, in its study, be led to think about nutritional activities as one of the fundamental phases of all life and will gain many basic ideas about food-getting and nutrition. (2) They will presumably gain an understanding of the dependence of man on plants and animals for food. As indicated below, the analytic study of man's food is included in the succeeding unit. There it is made more personal and individual than can be true in the present unit.

This unit has been placed in the latter part of the book so that it may be taught in the spring, when pupils can get outdoors to make observations and when plants are available for the experiments and observations of Problems 2 and 3. There is abundant opportunity for using knowledge already possessed by the pupils and for stimulating individual observation, the results of which can be brought to the class and used.

Ideas from preceding units that will be found most useful in the study of this unit are:

Unit 3. The nature of solutions.

Unit 5. (a) What elements and compounds are.

b) What happens during chemical change.

Unit 8. (a) Both plants and animals use food.

b) Both plants and animals respond to stimuli.

c) Living things are made of the same elements found in the non-living world.

d) Certain compounds are especially important in living things; among the compounds those of carbon are outstanding.

e) The activities of living things are carried on by living protoplasm organized into cells.

The ideas developed in the unit will be essential background for Units 10 and 11 of this book. Refer to the unit graph.

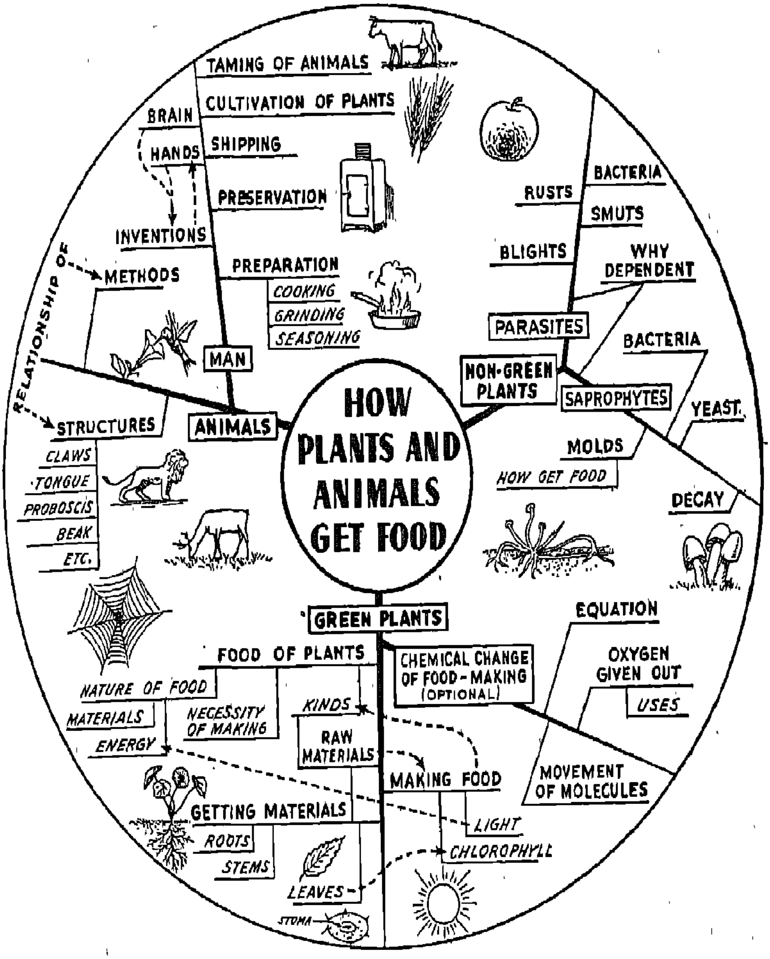

FIG. 13. GRAPH OF THE SUBJECT MATTER OF UNIT 9

INTRODUCTORY EXERCISES (P. 296). 1. Any animals may be named. It is preferable to have a variety. Six representative animals are listed here.

Lion. Catches food with claws and tears it with claws and teeth.

Snake. Some kinds squeeze their prey to death and then swallow them; other kinds catch small animals with their mouths.

Fish. Some take plant food in with water, and some pursue other animals and catch them with their mouths.

Frog. Catches flies, etc., with its swift-moving, sticky tongue.

Cow. Eats grass. Chews it with teeth.

Hawk. Catches small animals with its claws after swooping down on it and then uses sharp beak to tear it apart.

They get their food in different ways because their bodies are made in different ways.

2. Apple tree, mushroom, small green algae in pond, yeast plants, sunflower, fern, moss, etc.

Green plants can make their food from materials taken in through roots and leaves. Plants not green, that is, ones with no chlorophyll, cannot make their food, but get it from living plants or animals, or from decaying plant or animal material.

3. Food is the material that plants and animals use to build up their own bodies and to obtain energy for carrying on life processes.

They need it for the above reasons and for repairing and replacing cells and tissues that have been lost or injured.

4. Man is different from other animals in that he can make many kinds of foods from the different materials at hand. As he can grow things, he is not dependent on just what he finds in nature. He can also gather food from all over the world for use in any place.

5. (*a*) Carbon dioxide, water, minerals; (*b*) roots, leaves; (*c*) leaves; (*d*) sun; (*e*) chlorophyll; (*f*) animal food.

LOOKING AHEAD TO UNIT 9 (P. 297). The introduction to this unit can be successfully carried out in several ways:

a) The boys and girls may be asked to read this section and give their own observations of food-getting.

b) The teacher may introduce the unit in a talk of his own that is either a modification of the discussion in the text or an original talk.

c) The pupils may be led to discuss the questions, "How do animals spend the larger part of their time?" "Do plants need food?" "If plants need food, how do they get it?"

In any case the pupils should complete the "Looking Ahead" section with a clear idea that (*a*) all living things require food, (*b*) animals spend much of their time getting food, (c) they shall need to find out how plants get their food, and (*d*) animals, including man, all depend ultimately on plants for food.

PROBLEM 1: HOW DO ANIMALS GET FOOD? (P. 300)

This problem is unique in the extent to which pupils may be led to contribute their own observations for its solution. The teacher should *be sure to take full advantage of the opportunity.* The main ideas that grow out of the solution are:

1. The structure of each animal's body determines largely what food it can get and how it can get the food.
2. Because of his ability to think and to do things with his hands, man is different from animals in his ways of getting food. He uses tools to get food, raises plants and animals for food, develops new kinds of plants and animals, and transports, prepares, and preserves food.
3. All animals (including man) get their food directly or indirectly from plants.

EXPERIMENT 41. HOW DO ANIMALS TAKE FOOD INTO THEIR BODIES? (P. 301). The apparatus and materials needed are: As many aquaria and terraria as can be used. (Homemade cages and large glass jars are recommended.) As large a variety of animals as can be collected and cared for. Suitable materials for keeping notes.

The directions outline the procedure, but they need not be followed too closely. In this case give full play to pupil initiative. Let the boys and girls help plan the whole undertaking.

SELF-TESTING EXERCISES (P. 303). 2. Because they have different structures that fit them to capture and eat different kinds of food (and appetites that lead them to choose that kind of food).

Some examples are: (a) A frog's tongue is attached in such way that it can flip out in a hurry and catch a fly.
b) Birds with long, strong bills can get insects out of wood in trees.
c) Animals of the cat family have strong claws and teeth for catching and eating smaller animals.
d) A cow eats and digests grass because it has the kind of teeth and digestive organs for this food.

3. Answers will vary. Two examples are: (a) The elephant uses its trunk to carry food to its mouth.
b) Fish take in some food with the water that flows through their mouths and capture some by pursuing it and catching it with their mouths.

PROBLEMS TO SOLVE (P. 303). 2. Answers will vary. The material for this study can be obtained by observation or by reading in any book dealing with animals.

3. (a) Long snout, very long, slender tongue, strong claws for digging.
b) By sticking its long, sharp bill into an ant-hill and then pushing out its long, sticky tongue to catch the ants.
c) Because their lips are thin and split; thus they can grasp plants much nearer ground.
d) Claws that can be drawn back and pads on cats' feet. Pads on dogs' feet. Long, smooth, slender bodies of both.
e) Long neck and long legs that enable it to reach leaves of tall trees.
f) In large pouch, or fold of skin, that hangs down from lower half of bill.
g) To allow water to run down its throat. It cannot force water from its mouth into its throat. Must raise head so that gravity will make water run down throat.

SELF-TESTING EXERCISES (P. 307). 1. Man has a brain that can reason and plan, so that he does not need the structures characteristic of other animals for getting food. Can use his brain to plan tools and his hands to make and use them. Can raise food and send it from one place to another. Can plan how to improve his food and how to get food from new sources.

2. (a) Hunting with bow and arrows, guns, etc.
b) Fishing with various kinds of tackle.
c) Raising animals for food.
d) Raising plants for food.
e) Sending different kinds of food from one place to another.
f) Combining different kinds of foods to make new ones.
g) Preserving foods of many kinds for future use.

3. A savage would go out and get his meat by stalking it and shooting it with some kind of weapon. Would catch fish by spearing them or using a simple hook and line. Would use plants or parts of plants that grow wild, such as nuts, berries, certain roots, fruits, etc. Some might keep some sheep or chickens or some such animals to use as food.

Problems to Solve (p. 307). Some suggestions are: 1. Beaver, squirrels, man, ants, coneys.
2. Ants, bees, wasps, spiders.
3. Ants, bees, termites, man.
4. Ants, man.
5. Birds, bees, man.
6. Ants, man.
7. Men. (Bees may be mentioned.)

Self-Testing Exercises (p. 310). 1. One that lives entirely on plants for food.

Examples are: horses, cows, rabbits, squirrels, most caterpillars.

2. One that lives almost entirely on other animals.

Examples are: lions, owls, foxes, wolves, spiders, dragonflies.

3. Because even if one animal eats only animals, these animals feed on plants, and thus indirectly every animal needs plants.

4. A sample response is given: One of the favorite foods of the wolf is a sheep or a calf. The sheep and calf are strictly plant-eating animals. If there were no plants for them, they would die, and the wolf would soon be out of food. Thus the wolf really is dependent on plants for food.

Problems to Solve (p. 310). *Omnivorous* describes animals that eat both plants and animals.

Examples are: some of the apes, men, bears, rats, chickens, and many other birds.

PROBLEM 2: HOW DO GREEN PLANTS GET FOOD? (P. 310)

Although there are a number of places in the study of this problem where previous experiences of the pupils can be utilized, it differs fundamentally from Problem 1 because the solution is not immediately obvious. It must be worked out from observations and conclusions of scientists. Furthermore, it involves such intangible processes as the movement of water and gases into plants and a chemical change (photosynthesis) that cannot be demonstrated in the test-tube. However, the process is so fundamental to all life and to an understanding of so many problems that will come up later in the study of science and in living that the teacher should spare no pains in seeing that pupils grasp the basic facts and make the adjustment in thought and attitude implied by the main ideas of the problem. These are:

1. True foods for plants are such substances as sugar and starch (carbohydrates), which they must make for themselves from raw materials.
2. Carbohydrates are compounds of water and carbon. To make other kinds of food material, minerals are needed.
3. Most plants obtain minerals and water from the soil through their roots. They obtain carbon in the carbon dioxide they get from the air.
4. Very extensive root systems with many thin root-hairs fit plants to get the materials they need from the soil.
5. All (large land) plants have special circulation systems for carrying materials between roots and leaves.
6. Leaves have special openings and inner spaces to allow them to take in and give out gases easily.
7. With the help of chlorophyll (green material), leaves combine the carbon from carbon dioxide with water to form carbohydrates.
8. Plants make other kinds of food from carbohydrates and minerals.

Plans for Experiments 43, 44, 45, 46, 47, and 48 should be made in plenty of time to have the necessary materials ready. They cannot usually be picked up quickly from the laboratory cases. If pupils participate in the planning, they can gather much of the living material needed. If time is not available for having all the experiments performed by all pupils or as demonstrations before the entire class, a committee can be selected to carry out each experiment. The committees can be working simultaneously, and each committee can report to the class, usually with an exhibit of its discoveries or results.

EXPERIMENT 42. WHAT ARE CARBOHYDRATES MADE OF? (P. 313). The apparatus and materials are:

One-half teaspoon laundry or corn starch
One-half teaspoon sugar, any kind
Two test-tubes
Test-tube holder (may be made from a strip of cardboard or a piece of wire)
Bunsen burner (or other source of heat)

Decomposition of starch and of sugar when they are heated, as in this experiment, produces black carbon and water vapor. The vapor condenses into drops of liquid water on the side of the test-tube. It may be well to emphasize, for the pupils, the fact that starch or sugar may be perfectly dry and yet give out water when heated. This water comes from a chemical change, the decomposition of sugar.

EXPERIMENT 43. DOES SOIL CONTAIN MINERALS THAT WILL DISSOLVE? (P. 315). The apparatus and materials needed are:

Lamp chimney (or large bottle with bottom removed)
Ringstand with ring
Cheesecloth, four-inch square (or fine wire screen)
Glass tumbler (or beaker)
Small amount clean sand
One quart rich soil
One quart distilled water (or rain-water)
Two shallow dishes, one-half-pint capacity
Bunsen burner (or other source of heat)

The directions for the experiment are quite definite and can be followed easily by pupils. The term "minerals" means little to most pupils, and the residue left after the filtered water has evaporated usually has quite a "dirty" appearance. It may be well to show the pupils some pure samples of chemicals that can be used to nourish plants. These may be calcium chloride, magnesium sulphate (Epsom salts), potassium nitrate (saltpeter).

SELF-TESTING EXERCISES (P. 316). 1. Iodine test shows that plants contain starch (in leaves, roots, etc.) and that that amount increases; yet there is no starch in soil or air. Plants must make it from other substances.

2. A food must be used by a living thing to make new material like itself and to supply the energy needed to carry on the activities of a living thing.

3. Because they are composed of carbon and water. (*Carbo* is part of the word "carbon," and *hydrate* means a compound with water.)

4. Carbon dioxide and water.

5. Compounds of substances such as iron, calcium, etc., found in small quantities in our food and necessary for plant and animal growth.

Plants get minerals from the soil in which they grow.

EXPERIMENT 44. WHAT ARE ROOT-HAIRS? (P. 317). The apparatus and materials needed are:

Two squares of window glass, about 3 by 3 inches
Blotters (or towel paper)
Rubber bands
Radish, mustard, or cabbage seeds
Pan or dish
Water

The root-hairs develop some distance back of the very tip of each root and grow longer as they grow older. Thus the youngest and shortest root-hairs are those nearest the tip, while the oldest and longest ones are farthest from the root tip. The very end of the root is bare, for it is very young, and the hairs have not had time to grow. As the end of the root grows longer, more and more hairs appear just back of the tip.

The root-hairs of young plants can be easily demonstrated by placing corn grains or peas that have been soaked a day between pieces of wet towel or blotting paper which, in turn, are placed in one plate or dish covered with another to keep the paper moist. If the seeds are kept in a warm place, in two days many roots and root-hairs appear. The method described in the text is a little more trouble, but the specimens can be handled by an entire class without mechanical injury or drying and can be returned to the water for further growth.

Experiment 45. What Is a Plant's Root System Like? (p. 318). The apparatus and materials needed are:

Growing plants that may be dug from the ground
Strong digging tool—spade preferable
Large pan (or tub)
Water
Ruler with linear scale (or tape measure)

The measurement called for is merely the extent of the root system in the soil. Interested pupils may care to estimate the total length of the roots of one plant if all were placed end to end. It must be kept in mind that, no matter what the specimen, many roots, perhaps one-half the total, have been broken off in separating roots from soil. A large number of smaller roots are needed to make sure that the plant will have an adequate supply of moisture and minerals.

Experiment 46. Where Are the Water-Carrying Tubes of Plants? (p. 320). The apparatus and materials called for are:

Fresh daffodil (narcissus) or white carnation
Stalk of fresh celery
Young corn plant with stem visible above surface of soil
Branch of some woody plant, two feet long, with leaves still attached
Dry corn stalks
Red ink
Water
Tall jar or vase in which to stand plants
Sharp tweezers (or dissecting needle)
Sharp knife

A rather large quantity of ink should be mixed with the water for these experiments. Each plant put in the colored liquid should first have the end of its stem cut off under the water with a sharp knife. This exposes fresh surfaces to absorb the liquid and prevents the entrance of air bubbles that would prevent its rise through the xylem tubes. Often the desired results can be obtained within an hour or two. Sometimes the leaves begin to die within twenty-hour hours because of the injurious effects of the coloring material.

From florists one may be able to obtain the green dye that is used in coloring carnations for St. Patrick's Day. This is, of course, more effective with flowers than with leaves.

A very striking demonstration can be carried out with a rather old celery stalk that has the vascular bundles well colored with red ink. Break it part way across near the lower end in such a way that the vascular bundles ("strings") can be peeled out of the whole length of the stalk as the broken piece is pulled upward. In this way the bundles can be traced upward, and the clear red bundles against the white background bring gasps of surprise from the pupils.

SELF-TESTING EXERCISES (P. 322). Parts in parentheses may be omitted. 1. (a) A particle of water from the soil enters a root-hair cell.

b) From a root-hair cell it passes into (other cells of the root until it comes to the special cells of) vascular bundles that carry water.

c) (These cells together form a series of tubes up the stem, and) water goes up through the stem to branches.

d) (From tubes in branches) water enters leaf through a vein, (which is a vascular bundle in leaf and is connected with the vascular bundles of stem).

e) From a vein the particle of water passes to a cell near the vein.

2. (a) (Sugar is made in a leaf and dissolved in the liquid of a cell, since it must be in solution to travel from one part of a plant to another.)

b) Sugar solution goes from cell to cell of a green leaf until it comes to a vein.

c) Then it goes into special cells of vein, or vascular bundle, in which food is carried down through leaf to stem.
d) In special tubes in bark, sugar is moved down to roots.
e) From the tubes the sugar passes out into root cells and is used by them for food.

3. They are vascular bundles that make it possible for water to be carried to leaves from roots, and food from leaves to roots. (Their toughness is due to the strengthening cells in the bundles that help keep the stem stiff and erect.)

PROBLEMS TO SOLVE (P. 322). 1. Because the vascular bundles are broken, and the flow of water from the roots and food from the leaves is interrupted.

2. Because the vascular bundles that carry water up to the leaves and food down from the leaves are cut. A deep cut reaches through the food-conducting layer of bark into the sap wood, or new wood, through which most of the water is conducted.

EXPERIMENT 47. WHAT DOES THE EPIDERMIS OF A LEAF LOOK LIKE THROUGH A MICROSCOPE? (P. 324). The apparatus and materials needed are: Any common leaf from which the transparent epidermis can be peeled (geranium is good), compound microscope, glass microscope slide, cover glass, tweezers, small amount of water.

Choose a place in the leaf where there are no large veins. Break and tear the leaf with twisting motion. Often a bit of the transparent epidermis will project beyond the torn edge and can be pulled off with the tweezers. Another plan is to push the tweezers in a sloping direction through the leaf. Grasp a bit of the whole thickness with the tips of the tweezers. Then turn and pull this bit back along the leaf as if you were pulling thin paper off a wall. Frequently when this is done, a strip of the epidermis will pull free from the green tissue of the leaf.

When obtained, the bit of epidermis is laid in a drop of water on the slide. A cover glass is laid on top, and care is taken to see that all the space between the cover and the slide is filled with water. Focus with the low power, find a good place, and turn to high power. Although the stomata are visible with the low power, pupils will not see them easily unless they are seen with the high power. Figure 237 of the text and the directions for the experiment describe what should be visible. In case an onion or lily leaf is used, the shape of the cells will be different from those shown in Figure 237.

Self-Testing Exercise (p. 325). The diagram prepared by the pupil should be an approximation of one edge of a cut leaf, as shown in Figure 236. The teacher may well have all the pupils make the diagram at the same time after there has been ample time for study.

Experiment 48. Do Leaves Need Light in Order to Make Starch? (p. 325). The apparatus and materials called for are:

Healthy growing plant (nasturtium or geranium) in a pot
Light-proof material (card or black paper), two pieces for each leaf
Common pins
Iodine, weak solution
Alcohol (95% grain best; rubbing alcohol may be used)
Two beakers or cups
Small jar
Water
Pieces of glass (or cardboard)
Source of heat to boil water

When carried out as directed and the leaves are thoroughly soaked in iodine, the results should be unmistakable. The parts of the leaf or leaves from which the light has been excluded usually show a light brown color due to the iodine, but all around where the leaf was exposed to light, it should turn dark with the blue or black of iodine on starch, indicating that starch has been formed in the part of leaf exposed to sunlight.

(Caution: Be very careful not to ignite the vapor from the alcohol. Be prepared to smother the flames with a lid if the vapor is ignited.)

Self-Testing Exercises (p. 329). 1. Carbon dioxide and water (and chlorophyll).

2. Chlorophyll, or green coloring matter.

3. Because experiments show that in the parts of leaves kept out of sunlight no carbohydrates are formed.

4. Because chlorophyll is necessary for the process of photosynthesis by which carbohydrates are made in leaves.

5. Because the substance formed by the process of photosynthesis has new and different characteristics from materials used in process, that is, carbon dioxide and water, although the new substance is made up of the elements contained in these two materials.

PROBLEMS TO SOLVE (P. 329). 1. Answers will vary. Pupils' reports should list the substances tested and indicate whether each contains "much," "little," or "no starch."

2. Answers will vary. Pupils' reports should list the substances tested and state whether sugar was found or not. Each solid food should be crushed and soaked in a small amount of water to dissolve any sugar present. Then the "water" should be tested for sugar. The sugars shown to be present when the red or yellow precipitate forms are usually included under the head of "glucose." They are simple sugars, $C_6H_{12}O_6$, whereas cane sugar is a double sugar, $C_{12}H_{22}O_{11}$.

3. The plant grown in sunlight shows the more chlorophyll.

The experiment shows that light is probably necessary for the formation of chlorophyll in leaves.

4. Starch in the green parts only.

Because chlorophyll is necessary for making carbohydrates.

PROBLEM 3: HOW DO PLANTS THAT ARE NOT GREEN GET FOOD? (P. 330)

This problem includes the third variation of the food-getting problem in nature—food-getting by dependent plants.

The teacher should try to get pupils to develop a scientific attitude toward the dependent plants, which are so often regarded as organisms with spiteful "intentions." This scientific attitude should be produced when a pupil has really understood two points: (1) Certain plants are dependent because they must have food, but they cannot make it and therefore must necessarily "attack" dead or living things to get it. (2) Dependent plants, especially the saprophytes, are often helpful to man; in fact, if it were not for the bacteria of decay and the soil bacteria, we probably could not continue to live on the earth.

The main ideas brought out are:

1. Since chlorophyll is necessary for manufacturing food, plants that are not green must obtain their food ready-made.

2. Non-green plants give out chemicals that dissolve the food so that it can be absorbed.

3. Thousands of kinds of non-green plants live on materials that have been alive; in many ways these kinds of plants are useful as well as harmful.

4. Still other thousands of plants get their food from living plants and animals; this results in much damage to man and his plants and animals.

EXPERIMENT 49. HOW DOES BREAD MOLD GET FOOD? (P. 330). The apparatus and materials needed are: Dish (or tin coffee can) with tight cover, blotting paper (or towel paper), slice of fresh white bread, small amount of water.

Any situation that provides a practically saturated atmosphere and warmth is suitable for growing bread mold. Shaking some dust on the bread usually makes sure that there will be mold spores on the bread. The common black bread mold shown in Figures 240 and 241 usually appears and grows largest on the bread. However, other smaller types are quite common.

SELF-TESTING EXERCISES (P. 332). 1. They have no chlorophyll.

2. Mold sends hyphae into the material on which it is growing; these hyphae give out chemicals that cause a chemical change in the material and dissolve some of it. The dissolved food then can pass into the hyphae of the mold and be used by it as food for growth.

3. *Likenesses.* Both are long and slender with a hollow in the center where protoplasm is; they have a thin covering; they take in dissolved materials for use by the plant.

Difference. Hyphae take in actual food, while root-hairs take in only some of the raw materials (water and minerals) to be used by the green plant in making its own food.

4. Saprophytes get their food from the bodies of dead things. Parasites get their food by living on other living things and taking their food from these living things.

5. Neither can make their own food—must get it from other plants or animals.

PROBLEMS TO SOLVE (P. 333). 1, 2, 3. For these problems pupils should report either orally or in writing their results on what they learn. In connection with Problem to Solve 1, teachers may find Turtox Service Leaflet No. 32, "Culturing the Common Molds," helpful.

4. Most mushrooms use decaying plant and animal materials in soil as a source of food. Some use decaying tree trunks, etc., and others will be found growing on living trees.

5. In the form of spores.

6. Answer may include such things as soured or spoiled food, decayed articles of wood, moldy food or clothing, plants killed or injured by plant parasites.

7. Answers will vary with students. The problem calls for some kind of report.

PROBLEM 4 (OPTIONAL): HOW DO PLANTS MAKE FOOD? (P. 334)

This optional problem provides opportunity for applying knowledge of chemical symbols and the molecular theory to photosynthesis and also fills in the work of green plants in renewing the oxygen supply of the atmosphere. The main ideas are:

1. During photosynthesis molecules of carbon dioxide and water are broken up and rebuilt into sugar and oxygen molecules. The oxygen passes out into the air.
2. The oxygen provided during photosynthesis replaces that used by other living things.

SELF-TESTING EXERCISES (P. 335). 1. Chemical equation for photosynthesis:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

This means that, in the leaf, 6 molecules of carbon dioxide and 6 molecules of water combine to form 1 molecule of sugar and 6 molecules of oxygen. The 6 molecules of oxygen formed pass off into the air through the stomata of the plant.

2. The essential features of the diagram are shown in Figure 14. Many variations will occur in their representation. Pupils will usually prefer realistic, rather than abstract, representations of plants and animals. Be sure that pupils do not omit the use of oxygen for respiration of plants (at times when they are not making food).

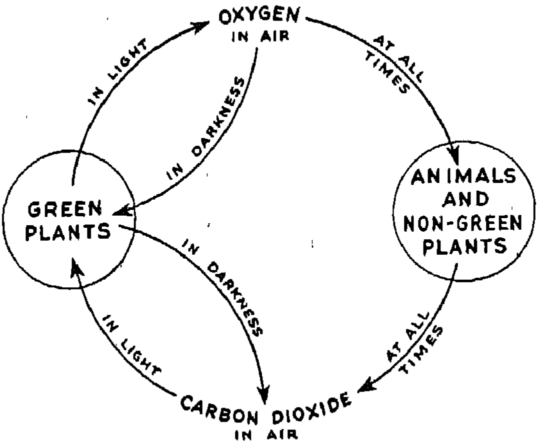

FIG. 14. OXYGEN-CARBON-DIOXIDE CYCLE

LOOKING BACK AT UNIT 9 (P. 335). The graph for this unit, page 195, might also be copied on the board to help complete the organization of this unit.

1. This answer should include these important ideas:

a) The structure of an animal determines what food it can get and how it can take food into body.

b) Man gets food in many different ways because he has a brain and hands.

c) All animals get food directly or indirectly from plants.

d) Green plants make food from carbon dioxide, water, and minerals, using light as an energy source, by photosynthesis.

e) Plants take in water and minerals from soil.

f) Plants get carbon dioxide and oxygen from air.

g) Non-green plants get food from other plants or from animals.

2. *Carbohydrates* are substances made up of a combination of carbon and water. Examples are sugar and starch.

A *carnivorous* animal is one that eats only meat (or animals) as food.

Chlorophyll is the green coloring matter in plants that makes it possible for plants to manufacture their own food.

The *epidermis* is the outermost layer of cells of a leaf or other plant (or animal) part.

An animal that is *herbivorous* eats only plants for food.

A *parasite* gets its food from a living thing.

Photosynthesis is the process by which green plants manufacture sugar from carbon dioxide and water with the help of chlorophyll and light.

A *saprophyte* gets its food from things that are not alive but have been alive.

A *stoma* is a small opening in a leaf through which gases enter and leave the leaf.

The *structure* of a thing means the kinds of parts it has and how they are put together.

The *tap root* is the main root of a plant.

A *vein* is a vascular bundle in the leaf.

Additional Exercises (p. 335). 1. The green water-plants carry on photosynthesis. As a result, oxygen is given off into water. Water animals breathe in oxygen and give out carbon dioxide. Plants take in carbon dioxide for use in photosynthesis. Plants obtain minerals also from waste materials from animals. Plants and animals can stay alive because each other's life processes furnish new supplies of carbon dioxide and oxygen. (See Figure 289, page 402.)

2. In winter most trees have no leaves, and water is not moving up stems in large amounts to replace that used in photosynthesis or lost from leaf by evaporation. In spring, when new leaves are forming and photosynthesis is again occurring, water transportation is greatly increased.

3. Potatoes sprouting in cellar do not have sufficient light for the formation of chlorophyll to make the leaves green.

4. Grass lying under a board will be yellow because it has not had light for the formation of chlorophyll. Yellow color is due to yellow coloring matter present in chloroplasts that shows when there is no chlorophyll to cover it.

5. By cutting the stems of white carnations and putting the cut ends into a green coloring matter. The dye goes up through the vascular bundles of the stems and out into the petals of the flowers.

6. Newly picked peas and sweet corn are high in content of sugar made during the process of photosynthesis. After they have been picked, sugar is changed to starch, and there is no longer the sweet taste of sugar.

7. The details of structural differences should be discovered and described by pupils. The horse and rabbit have upper and lower incisors with which they cut or nip off the grass. The cow has lower incisors, but no upper ones. It sweeps tufts of grass into its mouth by means of its rasp-like tongue. The grass is held against the sharp teeth by the tongue, and by a quick upward thrust of the head the grass is cut off.

8. The Venus's flytrap has leaves that are made of two toothed halves hinged in the center. Any large insects that alight on the leaves and touch "trigger hairs" cause the leaves to close rapidly and are apt to be caught and digested.

Leaves of pitcher plants are traps in which insects are caught and absorbed by the plant for food. The insects can't climb out because of long, sharp spines in the neck.

Sundew leaves are covered with a sticky liquid ("sundew") that entangles insects. The tentacles bend over and hold them tight to the leaves.

There is interesting material in Turtox Service Leaflet No. 11, "Insect-Eating Plants."

9. The lists will vary and can easily be checked individually. A few suggestions are: (*a*) dog, eagle, otter, dragonfly; (*b*) spider, ant-lion, man; (*c*) leopard, frog, cat, kingfisher, flycatcher, man.

10. Leaves need sunlight for making chlorophyll and for energy to carry on the process of photosynthesis. Since this is the process by which plants make food, it is important that all leaves get plenty of light.

11. When we eat any plant or animal food, we are taking in some of the energy from the sun that is stored in some green leaves during photosynthesis. We can say that we are eating sunshine indirectly.

14. Experiment with bacteria on washed and unwashed hands. Bacteria will grow much more rapidly if the gelatin is made with

clear soup (without fat). Careful washing with soap and water will remove most of the bacteria from the hands.

BULLETINS AND PAMPHLETS FOR UNIT 9

Agricultural Yearbook Separate
  No. 1659. *General Chemistry of the Soil.* 10c
Farmer's Bulletin
  No. 506. *Food of Some Well-Known Birds of the Forest, Farm, and Garden.* 5c

VISUAL MATERIALS FOR UNIT 9

Charts

Armour & Company, Chicago, Ill.
  Food Source Map of the U. S. (free)
Great Atlantic and Pacific Tea Company
  A Food Map of the U. S. (free)

Motion Pictures

Eastman Classroom Films
  "Cattle" (life on a cattle ranch)
  "Corn"
  "Dairies" (Wisconsin)
  "Meat Packing"
  "Sugar, Beet and Cane"
  "Wheat"
  "From Wheat to Bread"
  "The Green Plant"
Erpi Classroom Films, Inc.
  "The Frog"
  "Roots of Plants"
  "Leaves"
  "Fungus Plants"
  "The Wheat Farmer"
  "The Truck Farmer"
  "The Corn Farmer"
Swift & Company, Public Relations Department, Chicago, Ill.
  "Feeding the Nation" (free)
  "Chickie" (free)

Slides and Filmstrips

Keystone View Company
  Unit No. 13: Food (20 slides)
Society for Visual Education (filmstrips)
  "How Insects Get Food"
  "How Some Animals Get Food"
  "Mushrooms and Toadstools"
  "Plant Life I—Roots, Stems, Buds, Leaves, Flowers"

UNIT 10

Why Do We Eat Different Kinds of Food?

FUNCTION AND SCOPE OF UNIT 10. This unit presents in a simple, straightforward manner, without the sentimentalized appeals which are usually made to pupils, the scientific principles underlying the wise selection of foods and their use by the human body. The graph on page 215 will help the teacher see the unit as a whole.

Prerequisite ideas from preceding units are:

Unit 3. (a) The characteristics of a solution; (b) how solutions of food, oxygen, carbon dioxide, and other substances are essential to the existence of living things.

Unit 5. (a) Elements and compounds; (b) nature of chemical change.

Unit 6. Slow oxidation and energy release as applied to why our bodies need food and what they do with it.

Unit 8. (a) Chemical composition of living things; (b) cellular structure of living things; (c) protoplasm and its function.

This unit logically follows Unit 9, "How Do Living Things Get Food?" and its study will be more illuminating if pupils have previously studied that unit.

In addition to fitting into the series of biological units of *Book 1*, this unit provides basic material for units in *Book 2:* Unit 8, "How Do Our Bodies Work?" and Unit 11, "How Does Man Take Care of the Plants and Animals He Uses?"

INTRODUCTORY EXERCISES (P. 338). 1. Record of student's diet for a week. Teacher should insist on completeness and neatness and that the record be made day by day.

2. The clear, syrup-like material that is the living part of all plant and animal cells.

Yes, every living cell of my body contains protoplasm.

3. Small units of protoplasm with their protecting walls or membranes that make up the bodies of all living things.

They are found everywhere in my body.

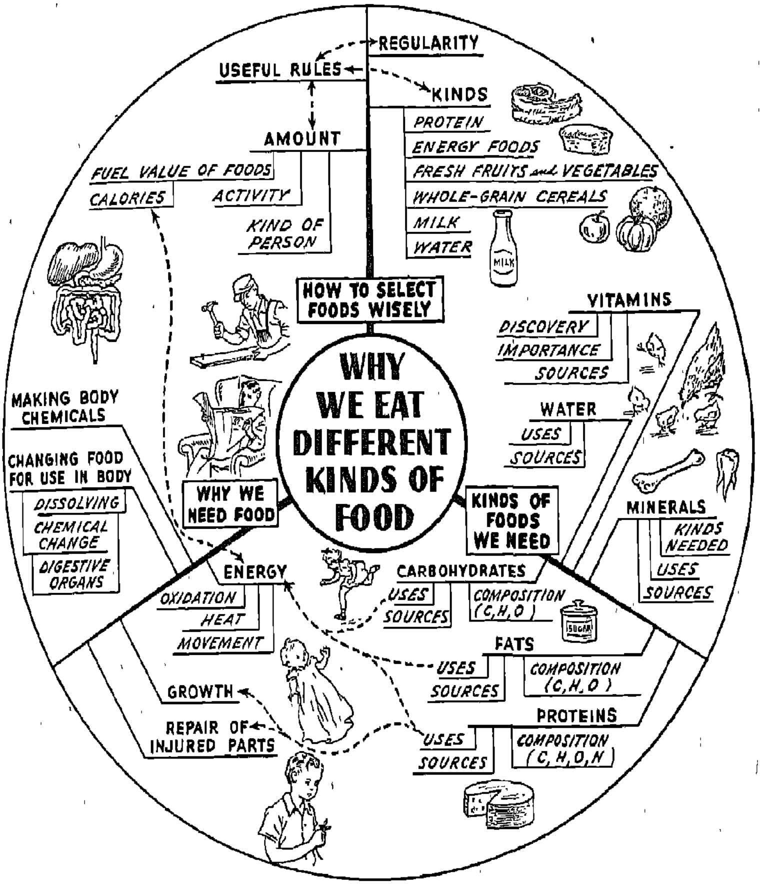

FIG. 15. GRAPH OF THE SUBJECT MATTER OF UNIT 10

4. Carbon, hydrogen, nitrogen, oxygen, calcium, phosphorus. The first four elements are the most abundant ones.

Some compounds are sugar, fats, protein, salt, water, hydrochloric acid, and calcium phosphate in bones.

5. (*a*) As a source of energy for carrying on activities.
b) To make new protoplasm and bone, etc.
c) To repair old or injured cells and tissues.
d) To supply materials for all chemicals made by body.

6. (*a*) It is broken up into pieces by teeth.
b) Some digestion is done by saliva in mouth.
c) It is sent down into the stomach, where gastric juices digest it and dissolve part of of it.
d) It passes on into the small intestine, where other juices complete the dissolving, so that it can be taken into the blood in solution.
e) It passes into the blood stream and in this is carried to cells of all parts of the body.
f) From the blood stream it goes into cells, where it is used with oxygen as a source of energy, or it may be stored for future use.

7. Chemicals found in certain plants and animals.

They are necessary in our diet to prevent certain diseases, such as scurvy, beri-beri, rickets, etc. If one gets too little of any one vitamin, he is not healthy and may develop a very definite disease like those mentioned.

9. Chemical reaction in which oxygen unites with some substance to make a new substance or new substances.

LOOKING AHEAD TO UNIT 10 (P. 339). This part of the unit introduces the idea of a well-balanced diet. Its purpose is to develop an interest in why our bodies need different kinds of foods and what these foods do for us. The simple appeal to pupils is, "Now you are old enough so that no one should need to tell you what to eat. You should know what to eat. Perhaps you do this now without really knowing why. It is much more interesting, however, to select your food when you know how to do it scientifically."

The introduction will be more interesting and valuable if the pupils keep and analyze lists of the foods they eat as the unit develops, as suggested in Introductory Exercise 1.

PROBLEM 1: WHY DO OUR BODIES NEED FOOD? (P. 341)

The idea that food provides the necessary energy for the body is used to introduce the first problem of this unit. Since digestion is presented as a kind of chemical change, reference back to Unit 5 should be made to refresh the pupils' minds as to what a chemical change is. Also, reference to pages 91-100 of Unit 3 (characteristics of a solution) will make it easier for the pupils to understand why starches must be changed into sugars before the digestive process can proceed further. The main ideas to be stressed are:

1. Hunger is a signal that the body gives a person to let him know he needs food.

2. Food must be dissolved, or digested, by our digestive organs before it can be used by the body.

3. Dissolved food soaks through the linings of the stomach and small intestines into tiny blood vessels and from there is carried by the blood to the cells.

4. In every part of the body, food and oxygen pass out of the blood into the cells.

5. In the cells a chemical change occurs; the dissolved food unites with oxygen and gives out energy for the cells.

6. *The cells of the body use food for these purposes:*

a) To provide energy and to keep the body at its proper temperature.
b) To build new protoplasm, bone, and nerve material.
c) To repair worn-out and injured parts of the body.
d) To get or make the chemicals needed in the body.

EXPERIMENT 50. HOW IS FOOD DIGESTED? (P. 344). The apparatus and materials needed are:

Boiled egg white
One-half gram of dry pepsin
Concentrated hydrochloric acid
Water
Small piece of wire screen
Two large test-tubes
Graduated cylinder

An approximation of the correct concentration of hydrochloric acid can be prepared by putting one medicine dropper full of concentrated acid in one pint of water.

The egg white is almost completely dissolved in the artificial stomach juice. The egg white is not noticeably changed in dilute hydrochloric acid.

SELF-TESTING EXERCISES (P. 346). 1. (*a*) To supply energy for activities of the body and heat to keep us warm.
b) To build new body material, that is, new protoplasm, new bone, new muscle, new nerve material.
c) To repair worn-out and injured parts of the body.
d) To supply materials for chemicals made by the body.

2. For oxidizing food materials to supply energy and heat for the body.

This is important because energy is needed for all activities of the body, and heat is needed to keep the body warm.

3. Uses fuel as a source of energy. Fuel or food is oxidized, and energy and heat are obtained by this process.

PROBLEMS TO SOLVE (P. 346). 1. In protoplasm of every living cell in the body.

2. All the time. Because we are constantly using energy for all activities of the body and to keep warm (except in hot weather).

3. For digestion of food, for keeping up body temperature, for breathing, for building up injured cells, etc.

4. To supply energy to his muscles.

5. By bringing in a fresh oxygen supply so that the cells will have a good supply for use in oxidation.

6. Waste product resulting from oxidation of food materials—carbohydrates, fats, and proteins—all of which contain carbon.

7. While running, one is using up much oxygen to oxidize material rapidly in order to supply energy for running. When one stops running, he continues to breathe rapidly in order to replenish the supply of oxygen.

PROBLEM 2: WHAT KINDS OF FOODS MEET THE DIFFERENT NEEDS OF THE BODY? (P. 347)

The ideas that answer this problem are fundamental to an intelligent attitude toward the selection of food. Included are the basic facts about carbohydrates, fats, proteins, water, and minerals. The story of vitamins is told as a thrilling example of scientific discovery, that is still unfinished, without attempting to have pupils memorize the names of all the vitamins, what disease each deficiency causes, and what foods contain each one. Table 8 and the figures provide facts for discussion and reference. Pupils should be able to name a few foods rich in each food substance, but should not be required to memorize the analysis of all foods listed. The main point of the problem is to get across the idea that a variety of food is necessary and why. The contributing ideas are:

1. Carbohydrates, such as starch and sugar, are food materials made of carbon, hydrogen, and oxygen; their main use in the body is to provide energy.
2. Fats, such as fat meat and butter, are made of carbon, hydrogen, and oxygen and are also of value chiefly for the energy they contain.
3. The body stores both carbohydrates and fats for future use.
4. Proteins, composed of carbon, hydrogen, oxygen, and nitrogen, are essential for the formation of new protoplasm.
5. The body must have water to form protoplasm, to help carry on chemical changes, and to dissolve and transport materials in the body.
6. Our food must contain minerals to provide materials for building the body and for making chemicals that the body needs; calcium, phosphorus, iron, and iodine are the four mineral elements that are likely to be deficient in diets.
7. Vitamins, special substances in foods, are needed in very small quantities to keep our bodies in good condition.

a) Lack of proper kinds of vitamins is the cause of some diseases—scurvy, beri-beri, rickets, pellagra.

b) We usually get plenty of vitamins when we eat a well-balanced and varied diet.

SELF-TESTING EXERCISES (P. 359). 1. The characteristics and uses of the different classes of foods are given in the table on page 220.

CLASS OF FOOD	ELEMENTS IN THIS FOOD.	COMMON SOURCES OF THIS FOOD	USE IN BODY
Carbohydrates	Carbon, hydrogen, oxygen	Bread, sugar, cereals, potatoes, beans, candy, some fruits, as dates and raisins, etc.	Provide energy and warmth.
Fats	Carbon, hydrogen, oxygen	Butter, oils, fat meat, lard, nuts, cream, cheese, etc.	Provide energy and warmth.
Proteins	Carbon, hydrogen, oxygen, nitrogen. Some have sulphur and phosphorus	Lean meat, eggs, fish, cheese, milk, navy beans, chicken, etc.	Make protoplasm: also provide energy.
*Water	Hydrogen, oxygen	Water and other beverages. Juicy fruits and vegetables	Dissolves and carries food; forms large part of protoplasm and blood; carries wastes away, keeps body cool.
*Minerals	Iron, phosphorus, calcium, sulphur, copper, iodine, etc.	Milk, cheese, meats, green vegetables, sea foods (for iodine), fruits	Build bones and teeth; also used in certain important gland extracts; iron and copper for new blood cells.
*Vitamins	Largely unknown	Different sources for various vitamins: milk, citrus fruits, cod-liver and halibut-liver oil, sunshine, unpolished rice, etc.	Prevent certain diseases (beri-beri, pellagra, scurvy, and rickets).

*Not considered as food substances in the sense that they provide energy but since they are essential materials that are obtained from food and water they are considered along with food substances.

2. Responses will vary from pupil to pupil.

3. To help prevent rickets, because sunlight is weak and often shut off, and because babies' bodies are covered with clothes and cannot get the needed rays of the sun. In summer there is more sunlight, and the babies do not have to be covered with clothes that keep the sunlight from them.

PROBLEMS TO SOLVE (P. 360). It might be well to have pupils give the data for their experiments in tabular form, as suggested below:

CLASSES OF FOOD	HOW TESTED	FOODS TESTED	RESULTS
Fats			
Proteins			
Minerals			
Water			

PROBLEM 3: *HOW CAN WE SELECT OUR* FOODS WISELY? (P. 361)

Selecting an adequate diet is not a difficult matter. The understanding of a few scientific principles will enable boys and girls to interpret and use simple rules in the wise selection of foods.

There is a fine opportunity here for the science teacher to coöperate with the school health department, physical education department, school lunchroom, and the home in developing the desired habits of eating.

The rules presented in this problem are based upon scientific analyses of energy values of different kinds of foods and the energy needs of different individuals. The consequences and dangers of overeating and "reducing fads" are clearly brought out.

The concluding part of the problem uses the principles that have been developed in the first part of the problem and in the unit as a whole as the basis for formulating a simple set of rules that can be followed by the pupils in selecting their own foods. The main ideas to be developed are:

1. People vary in the amounts of food they need; healthy, well-trained appetities may be followed in knowing how much food to eat.

2. Scientists measure the fuel value of a food by finding how much heat the food gives out when it is completely oxidized; fuel value of a food is measured in calories.

3. By knowing the amounts of oxygen a person uses, the amount of carbon dioxide he gives out, the heat his body produces, and the amount of work he does, scientists can calculate how much energy that person uses in a day and how much food he needs.

4. Each healthy person should eat enough to keep him feeling strong and energetic throughout the day and, if he is growing, to provide for a normal increase in his body size.

5. A person should reduce his weight only under the advice of a competent physician.

6. Most people can select a satisfactory diet by following certain general rules.

SELF-TESTING EXERCISES (P. 370). 1. *Rule 1. Eat regularly three meals a day.* Most people find that their digestion and rest and elimination are better when they eat regularly. (Pupils' answers should be accepted if they are at all reasonable, since the textbook does not discuss the reason for this rule. *Do not accept* as reasons the material that follows the rules on page 370.)

Rule 2. Eat a serving of food rich in protein twice a day. Everybody must have plenty of protein to make new protoplasm for its cells.

Rule 3. Eat at least two generous servings of vegetables daily, one of them a green, leafy vegetable. These provide (*a*) minerals, (*b*) vitamins, and (*c*) bulk to stimulate the large intestine to empty itself regularly.

Rule 4. Eat two servings of fruit each day, one of them raw. Fruits provide bulk for the bowels and certain vitamins not very abundant in most vegetables. Cooking destroys some vitamins.

Rule 5. Avoid overeating of sweets. They spoil one's appetite for a variety of foods and may tend to cause diabetes (and tooth decay).

Rule 6. Eat a whole-grain cereal or two slices of whole-wheat bread each day. These also are good sources of a certain vitamin and of minerals and bulk for the bowels.

Rule 7. If you are young, drink at least a quart of milk a day. Milk is one of our best sources of minerals and of certain vitamins. Growing bodies need more calcium and phosphorus for bones and teeth than bodies that have stopped growing.

Rule 8. Drink four to six glasses of water each day. Plenty of water keeps the body in better condition and helps eliminate wastes through kidneys and large intestine.

PROBLEMS TO SOLVE (P. 371). 1. Meals are too heavy in carbohydrates, fats, and proteins and too light in fruits and vegetables. No uncooked fruits and no green leafy vegetables. No whole-grain bread, valuable for its vitamins. More meat than necessary. Coffee at each meal is not a good idea. Milk should be drunk instead in order to have the necessary supply of that important item. Fried foods, cream, and gravy give an over-supply of fat. Hot biscuits, bread twice, potatoes twice, and beans and cake give too high a proportion of carbohydrates.

2. Difficult to supply fresh meat and eggs, fresh milk, and especially fresh fruits and vegetables.

3. Submarine did not carry sufficient supplies of proper kinds of food to prevent scurvy, that is, oranges, lemon juice, and tomato juice, that have the necessary vitamins.

5. Days of greater physical activity call for more food, because more energy is needed and more cells are worn out. Food intake should be reduced on inactive days, because less energy is required.

LOOKING BACK AT UNIT 10 (P. 372). Refer to the graph on page 215.

1. Big ideas of the unit (not all of which may rightly be called principles of science) are:

a) Nothing moves without the use of some kind of energy; food is the source of energy for the body.

b) Food must be dissolved, or digested, by the digestive organs, before it can be used by the cells of the body.

c) When food is oxidized, energy and heat are released.

d) Food is used to provide energy and warmth, to make new protoplasm for different parts of the body, to repair worn-out and injured parts of the body, and to manufacture the chemicals needed by the body.

e) There are six kinds of substances needed to make healthy bodies: carbohydrates and fats for energy or fuel; proteins to provide new protoplasm; water, important in several ways; minerals for making bones and teeth and certain chemicals secreted by the glands; vitamins to keep the body in good condition.

f) One should eat enough to keep feeling strong and energetic throughout the day, and he should eat a well-balanced and varied diet in order to get the various kinds of things needed by the body.

2. A *vitamin* is one of the chemicals from different sources that the body needs to prevent certain diseases.

Meat is largely *protein*, a compound made up of carbon, oxygen, hydrogen, and nitrogen.

A *calorie* is a unit for measuring the amount of heat produced by a food; it is the amount of heat needed to raise the temperature of 1000 grams (about a quart) of water one degree centigrade.

Digestion is the process of dissolving the food taken into the body, so that it can be used by the body.

Fuel value means the amount of energy produced when a certain amount of any given food is oxidized.

The *thyroid gland* is an important gland that secretes a chemical necessary to the proper development of the body; iodine is needed by the thyroid gland to make its chemical.

Fuel foods are the ones that give us warmth and energy when they are used by the body.

Rickets is a disease of the bones caused by a lack of vitamin D.

ADDITIONAL EXERCISES (P. 372). 1. A bird. Body temperature is kept up by oxidizing food materials, and it would take a larger amount to keep the temperature up to the higher level characteristic of birds.

2. Fuel put into an automobile furnishes heat and energy for making the car move. Food we take into our bodies not only provides heat and energy, but also provides materials for growth, for repair of tissues, and for chemicals made by body. Fuel put into an automobile cannot do these last three things.

3. Suggested ways are: (*a*) from hands of food handlers; (*b*) from dust and dirt in air; (*c*) from feet of flies; (*d*) from contaminated water; (*e*) by use of human wastes as fertilizers, as is done in some countries.

4. Weigh an apple and record the weight. Put it in a dry place or in an oven at low temperature, where it will gradually dry out.

Weigh at intervals until the weight remains the same for several weighings. Subtract the final, or dry, weight from the original weight to determine the amount of water lost. Divide the amount lost by the total weight to determine the percentage of original weight that was water.

5. Responses depend on the data secured, but they may include refrigerators, paper and cellophane wrappings, glass cases, screens—both cloth and wire.

6. Because we lose much more heat from our bodies when the temperature is low, and we need more food to provide larger supply of heat than we need in summer.

7. Oxidation of fuel food material proceeds at a more rapid rate, and more heat is produced than when not exercising.

8. The basis for understanding this exercise is laid in the study of photosynthesis, pages 326-327 and 334-335. Almost any biology or botany book will emphasize the change of radiant energy of sunlight into chemical potential energy that is stored in the carbohydrates formed during photosynthesis.

9. The menu should follow the rules given on page 370 of the text and should be reasonable in the amount of food provided for adults who are (*a*) active and (*b*) sedentary.

BULLETINS AND PAMPHLETS FOR UNIT 10

Agriculture Circulars
  No. 15. *Proximate Composition of Fresh Fruits.* 5c
  No. 146. *Proximate Composition of Fresh Vegetables.* 5c
  No. 205. *Iron Content of Vegetables and Fruit.* 5c
  No. 549. *Proximate Composition of Food Materials.* 15c
Agriculture Department
  Food and Life (Yearbook of Agriculture for 1939). $1.50
Agriculture Yearbook Separates
  No. 1676. *Human Food Requirements.* 5c
  No. 1680. *Food Composition.* 5c
Children's Bureau Folders
  No. 23. *Noon Meal at School.* 5c
  No. 25. *Substitutes for the Sun.* 5c
Farmers' Bulletins
  No. 808. *What the Body Needs.* 5c
  No. 1313. *Good Proportions in Diet.* 5c

No. 1359. *Milk and Its Uses in the Home.* 5c
No. 1374. *Care of Food in Home.* 5c
No. 1383. *Food Values and Body Needs, Shown Graphically.* 10c
Home Economics Bureau
Eat the Right Food to Help You Keep Fit. 5c
Merck and Company, Inc., Rahway, N. J.
Vitamins in Nutrition
The Story of Vitamin B_1
Public Health Bulletin
No. 192. *Endemic Goiter.* 35c
U. S. Bureau of Fisheries Document
No. 967. *Iodine Content of Sea Foods.* 5c
U. S. Department of Agriculture Bulletins
No. 310. *Digestibility of Some Animal Fats.* 5c
No. 975. *Food Values, How Foods Meet Body Needs.* 10c
U. S. Experiment Stations Bulletin
No. 28. *Chemical Composition of Food Materials.* 10c

VISUAL MATERIALS FOR UNIT 10

Charts and Posters

Superintendent of Documents, Washington, D. C.
Health Education Poster 4
Weight-Height-Age Tables for Boys and Girls. 5c
Nutrition Charts 1-11. Each 23 x 15 in., illus. 50c per set
100-Calorie Portions of a Few Familiar Foods in Terms of Ordinary Household Measurements and of Quantities Commonly Purchased. Poster. 19 x 24 in. 10c

Motion Pictures

Eastman Classroom Films
"Food and Growth"
"Food Series—Vitamin B_1"
"Food Series—Vitamin D"
"Good Foods—A Drink of Water"
"Good Foods—Bread and Cereals"
"Good Foods—Fruits and Vegetables"
"Good Foods—Milk"
Health Products Corporation
"The Search of the Elusive Vitamins A and D" (free)

UNIT 11

How Do Plants and Animals Live Together?

FUNCTION AND SCOPE OF UNIT 11. Unit 8 of *Science Problems, Book 1,* is a comparative study of plants and animals; Unit 9 presents the problems encountered by living things in getting food; and Unit 10 deals with the dietary problems that face human beings. This unit (Unit 11) is logically related to these preceding units in that it centers attention upon the interdependence of plants and animals in securing the necessities for maintaining life. Also, the unit provides an appropriate conclusion for the biological material of *Book 1.*

Clearly presented is the idea that there is ceaseless competition for survival among living things. Since man is one of the numerous species of living things, he, too, is engaged in the constant struggle for survival. Logically following the foregoing idea is the idea that out of the ceaseless struggle for existence there naturally comes a survival of certain species and a more or less definite balance in the numbers of individuals in a species. Refer to the unit graph.

An understanding of the main ideas of the unit should lead to a deeper appreciation of the "problems" and activities of the living things of the immediate environment (including human beings) in the light of their relationship to each other.

We know that first-hand experiences are indispensable to effective learning. Consequently, much carefully directed observation should be made as the unit develops. This is best done in field trips under the supervision of the teacher. However, students can visit specified places or make specified observation individually or in small groups. Student projects, such as rearing ant colonies, observing their behavior, and keeping careful records of these observations, should be used to enrich other experiences the pupils may have during their study and to care for individual interests.

If Experiment 51 has not already been started, it should be planned and started immediately.

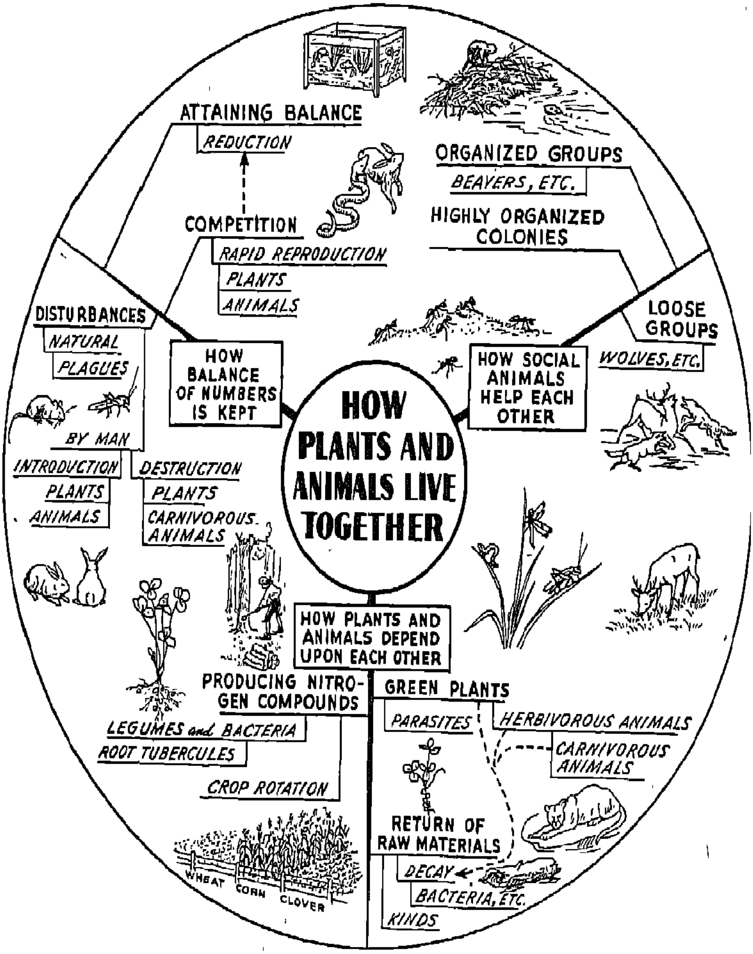

FIG. 16. GRAPH OF THE SUBJECT MATTER OF UNIT 11

INTRODUCTORY EXERCISES (P. 374). 1, 2. Pupils' lists may include some of these things:

	FOOD	CLOTHING	SHELTER	MEDICINE	PLEASURE
PLANT	Fruits Vegetables Flour, all cereals Maple syrup Coffee Tea Cocoa Sugar Spices Flavorings	Cotton Linen from flax Rayon Straw hats Rubber Fibers of banana leaf (Philippine cloth)	Wood for building Resins (varnish) Lacquers	Quinine Ephedrine Cocaine Castor oil Witch hazel Digitalis Camphor Cascara Licorice	Flowers Shade trees All plants used in landscaping Perfumes
ANIMAL	Meat Milk Fish, fish products Eggs Butter Lard	Silk Wool Leather Fur	Animal skin (tents)	Serums Cod-liver and halibut-liver oil	Pets Riding horses Zoos

3. A community is a group (of people, of other animals, of plants, or of all three) living together.

4. Plants compete for available light, water in the soil, and minerals in the soil.

5. Animals compete for food, water, and mates.

6. Although many young are produced every year, the number stays about the same because disease, enemies, and various accidents kill many of the young animals before they can grow up.

7. Green plants not only supply food for fish, but, more important, they give off oxygen during the process of photosynthesis. This helps keep an adequate supply of oxygen in the water for the fish. When the plants were destroyed by the storm, this oxygen supply was cut off.

8. Yes. Some of their helpful activities are:

a) They bring about the decay of dead plant and animal bodies.

b) They change the materials from decayed bodies to materials plants can use and thus help provide food for animals and man.

c) Some are able to take nitrogen from air and make it available to plants. This is very important because it helps man keep up the supply of nitrogen in the soil.

d) Some bacteria help make substances that are useful in industry—certain kinds of alcohol, acetic acid, etc.

9. No. The kind of conditions he needs to live and the building of dams and comparatively complicated homes would be difficult to meet alone. It would take one beaver too long to cut down trees, store food, etc. It could be done, but not so satisfactorily as in a group.

10. Young oysters are used as food by many of the sea animals; the undersea conditions and various diseases all tend to decrease the chances for the oysters to reach maturity.

LOOKING AHEAD TO UNIT 11 (P. 375). The introduction to this unit should help orient the pupils' thinking along these lines: (1) It should make them aware that living things depend on each other. (2) It should show that there is a ceaseless struggle for the necessities of life. (3) It should show that in the struggle for life the strongest survive. (4) The illustrative examples (with those supplied from pupils' experiences) should arouse keen interest in the material of the unit.

PROBLEM 1: HOW DO PLANTS AND ANIMALS DEPEND UPON EACH OTHER? (P. 379)

This problem is unique in that the material (or much of it) is applicable to the pupils' own environment. As the different ideas are developed, application of these ideas should be made to include local plant and animal populations. For example, as carnivorous animals are studied, the class may make a list of all those the pupils know and add to it as they learn of others that live in the region.

The mere *definition* of kinds of plant and animal groups and of processes that relate these groups is not enough. During the learning process, much stress must be placed upon the interaction of these groups and processes in order that pupils may be able to formulate their own answers to the question asked by the problem title. The main ideas are:

1. Some animals (herbivorous) feed upon plants only; other animals (carnivorous) feed upon animals only.

2. Parasitic plants get their food from green plants.

3. Green plants are the ultimate source of food for all living things.

4. The food cycle in nature is the process in which the supply of raw materials is kept up.
a) Green plants change raw materials from soil and air into food.
b) This food is used by other plants and by animals.
c) When plants and animals die, bacteria and other fungi cause them to decay, and the materials go back to the soil and air.

5. Bacteria living on the roots of leguminous plants take nitrogen from the air and put it into the soil, where it can be used by other plants.

6. Farmers rotate crops to conserve the fertility of soils.

SELF-TESTING EXERCISES (P. 388). 1. Pupils' essays should include these points:
a) Materials in the food cycle move from soil and air to plants, from plants to animals, and from plants and animals back to soil and air.
b) All living things depend upon green plants.
c) All raw materials for food manufacture come from soil and air.
d) The materials of all living things are returned finally to soil and air by the organisms that cause decay.

2. A parasite is a plant or an animal that gets its food from other living things.

Dodder is a parasite because it gets both food and water from living green plants and does not make any food at all. Although mistletoe has chlorophyll and can manufacture food, it is a parasite because it takes water and minerals from the trees on which it grows.

PROBLEMS TO SOLVE (P. 388). 1. Answers will vary. One example is: A hawk catches a rabbit and eats it. The rabbit has lived on clover and other green plants that make their food.

2. Nitrogen compounds are absolutely essential to proper plant growth and development. Without nitrogen compounds plants and animals would have no food supply. In a community without

bacteria to capture the nitrogen, either the nitrogen compounds or the food supply must come in from other sources.

3. Man usually has a very disturbing effect on a plant and animal community. Some of these things may happen:
a) He may plow the land, thus destroying the homes and food supply of small birds and other animals and driving them away.
b) The departure of these animals will deprive animals who live on them of a food supply, and they will have to go elsewhere.
c) The cutting of trees may make a sunny area out of a shady one, so that different kinds of plants will grow up in the region.
d) Plowing the soil will open up the possibility of erosion and the loss of valuable top soil and minerals so that soon the soil will not be fertile enough for good plant growth unless the land is carefully used.
e) If the natural enemies of some of the animals are destroyed or driven off by man, the remaining animals may increase in such numbers as to become pests.

4. The plants will grow very poorly and may finally dry up and die. When plants are small or scarce, animals do not have enough food. The water supply may get so low that animals cannot get enough water.

6. One should find on the roots little knots containing the bacteria that take nitrogen from the air.

7. The chief points about the partnership in lichens are:
a) They consist of two plants, a fungus and an alga, growing together so that they look like one plant.
b) The fungus absorbs available water and minerals and protects the alga from drying out and from injury.
c) The alga, having chlorophyll, manufactures food, which the fungus gets by sending hyphae into the alga cells.
d) Living together, these two plants can grow under conditions that would be impossible if they lived alone.

PROBLEM 2: HOW DO SOCIAL ANIMALS HELP EACH OTHER? (P. 390)

This problem is a brief study of types of social animals, from the simplest to the more complex. Each representative group is carefully illustrated by means of a single example rather than by means of encyclopedic treatment. The idea of *division of labor* among animals (other than in human society) will probably be new to many pupils, and since this is the climax of the problem, much of the emphasis of the teaching should be directed toward this idea.

The establishment and observation of ant colonies, and wherever facilities permit, the use of especially constructed observation beehives, provide splendid first-hand experiences for making this part of the unit real for the pupils. If the teacher wants to develop relationships between science and social studies, he may have pupils compare and contrast division of labor in social animal groups with that in human groups.

The main ideas of this problem are:

1. Some kinds of animals form groups to secure food more easily or for common protection.

2. Some animals have a well-developed social life that involves a division of labor.

3. Animals in a colony live together more successfully than an individual can live by himself.

Self-Testing Exercises (p. 395). 1. (a) A group can build dams more quickly and easily. Dams are important, because they provide the proper kind of home, protection, and food for colony.
b) A group can collect food and store it under water more easily.

2. (a) The queen lays all the eggs for the colony.
b) The workers gather food for the whole colony.
c) The worker honey-ants, that act as honey storage casks, are working for the whole colony.

3. We mean that the work to be done is divided among different classes of members of the colony, and each class does his own kind of work for the benefit of the whole group.

Problems to Solve (p. 395). 1. (a) Beavers and ants are alike in these ways: (1) All work for common good.
2) Many animals live in each group.
3) Each group prepares home best fitted for its use.
b) They are different in these ways: (1) Work of beavers is not delegated to special individuals.

2) A pair of beavers could live and perpetuate the species, but a pair of ants would require the help of other ants in order to exist.

3) Methods of working differ.

c) Yes. Ants are more highly developed as social animals because their division of labor is carried out to a greater extent than that of beavers.

2. (a) Ways in which ants and human beings live and work together are alike: (*1*) They live in groups.

2) Different members of each group do different kinds of work.

3) Both are more successful when they coöperate.

b) They differ in these ways: (*1*) People are free to change groups they live in and to select kinds of work they will do; ants are not free.

2) Ants coöperate instinctively; people coöperate intelligently and may refuse to coöperate in many places.

3. Responses depend on individual study.

4. Answers will vary. A sample response might be: (a) Father earns the money; (*b*) Mother cooks and sews; (c) sister makes the beds; (*d*) brother cuts the grass, etc.

5. Division of labor makes it possible for the colony to accomplish more work, since there is no duplication of effort and since all individuals are working for the benefit of the colony.

6. There may be different opinions on this question, but it would seem that the individuals are less independent in a group. If they depend on someone else for certain kinds of things, they may be without these things if something should happen to the provider. For example, individuals in an ant colony that depend entirely on certain workers for their food would starve if something happened to the workers and the remaining ants were not able to provide their own food.

PROBLEM 3: HOW IS THE BALANCE OF LIFE MAINTAINED? (P. 395)

This problem is the logical outgrowth of the preceding problems of the unit, and it provides a valid culmination by bringing together the material presented earlier. One of the most striking ideas developed here is that vast numbers of living things are constantly being produced. Without the intervention of natural environmental conditions and plant and animal enemies, the entire world would soon be hopelessly overpopulated. However, the struggle for the necessities of life limits living things to the number that can be supported by a given environment. Thus, the balance of life is maintained. The struggle among living things for existence and man's disturbing effect upon the environment are the focal point of the problem. The main ideas to be presented are:

1. The natural rate of reproduction of living things is so great that, if unchecked, the world would be over-populated in a short time.
2. The conditions, materials, and space necessary for the support of living things are limited.
3. The struggle of living things for the necessities of life results in a balance of life.
4. The balance of numbers of living things may be easily upset.
5. Man is the greatest disturber of the balance of life.
6. Man must use the best scientific knowledge available to avoid upsetting the balance of life so greatly that the results will be harmful to him.

SELF-TESTING EXERCISES (P. 400). 1. Because so many more living things are produced than can be cared for. There is not enough space, food, or water for so many.

2. Because of the factors mentioned in exercise 1, plus the fact that plants and animals have many enemies that prey on the young.

EXPERIMENT 51. HOW IS A BALANCED AQUARIUM CONSTRUCTED? (P. 402). The apparatus and materials are:

Aquarium, 6-gallon or more
Sand
Water, pond or faucet
Water plants (Vallisneria, Sagittaria, Elodea, Myriophyllum)
Three or four snails
Two or three tadpoles
Four or five small fish (mud minnows, catfish, or sticklebacks)
Fresh-water clam
Piece of glass to fit top of aquarium
Rubber tubing, three feet long
Small stones

This experiment should be started weeks before the class arrives at the study of the problem.

A flat pane of glass as a cover for the aquarium, rubber tubing for siphoning in the water, and long sticks for helping imbed the plants in the sand are desirable. Place the small rocks closely about the base of the plants to keep them from uprooting.

Have the pupils participate in the planning and construction of the aquarium as a class project. If several aquaria or other containers are available, divide the class into small groups and allow each group to plan and construct its own aquarium. In all cases where it is at all practical, plants and animals should be collected by the pupils on field trips. Buy animals and plants only as a last resort. Be sure to put only animals and plants that live in quiet water in aquaria, since those accustomed to living in running water may die for lack of oxygen in an aquarium. Use plants sparingly, as too many plants will cause the water to become cloudy.

If the aquarium has too much light, it will become clogged with algae. There is more danger from too much sunlight than is usually realized.

Some snails should be used, as they are valuable scavengers. Probably catfish, mud minnows, or sticklebacks would be of more interest than goldfish or other fancy fishes that one ordinarily uses in home aquaria.

Much can be done in clear pint, quart, or gallon glass jars if no fish are put in and care is taken not to crowd the jars with plants. The best way to start such an aquarium is to collect water plants from a local pond or lake with a garden rake. A strictly limited sample of the plants is put in the jar with water from the lake. The jar is placed in a north window or other lighter place that does not receive direct sunlight. No sand is necessary. Usually there will be enough small animals or plants to make the jar interesting as soon as it is examined carefully. Additional snails, insect larvae, and other small animals may be picked out of the extra plants that are collected. A few jars will soon turn cloudy with bacteria, and the plants will decay. Most animals will come to the surface to get the oxygen the dead plants can no longer give out. These jars illustrate an unbalanced situation. If let alone, they will usually attain a balance, and often green plants will begin to grow again.

These Turtox Service Leaflets contain valuable suggestions: No. 5, "Starting and Maintaining a Balanced Fresh-Water Aquarium"; No. 23, "Feeding Aquarium and Terrarium Animals"; and No. 48, "Aquarium Troubles: Their Prevention and Remedies." They may be obtained from the General Biological Supply House, 761 East 69th Place, Chicago, Illinois.

Have pupils write out plans before any work is attempted and keep careful records as to the steps undertaken in establishing the aquarium, why these steps were undertaken, and the outcomes of these efforts.

SELF-TESTING EXERCISES (P. 405). 1. Just enough young plants and animals grow up to take the place of the old ones that die or are killed.

2. Diagrams by pupils of exchange between plants and animals in a balanced aquarium will vary. They should include the main points made by Figure 289, page 402.

3. Animals that cause a plague are brought into balance by:
a) Disease that attacks them and spreads among them.
b) Increase in their natural animal enemies.
c) Lack of enough food to feed so many extra animals.
d) Unfavorable weather conditions.

SELF-TESTING EXERCISES (P. 408). 1. Having the proper number of the different kinds of plants and animals in a community to provide each other with the necessary food and living conditions and to keep each other in check so that no one kind becomes a nuisance.

2. The natural enemies of the over-abundant animals increase in numbers more rapidly than usual. These reduce the over-abundant kind to the natural balance number.

3. Some examples are: (a) Introduced rabbits into Australia.
b) Plowed up prairies, loosening the soil, which resulted in duststorms.
c) Cut down forests, resulting in terrific floods.

d) In one of the national forests the natural enemies of the deer were all killed off, with the results that too many deer grew up and there was not enough food for all of them. The forest was badly damaged by the hungry deer, and many deer starved to death.

4. Because dust storms, floods, plagues of animals and insects, and diseases may result if the factors in nature that control these things are destroyed.

PROBLEMS TO SOLVE (P. 408). 1. A plant or animal in one country may have enough natural enemies to keep it in check. In another country the natural enemies may be lacking, so that the plant or animal becomes a pest.

2. Yes. Because in nature a state of balance is the normal state, and it is only when man disturbs the balance or when other unusual conditions occur that it is upset. Usually the living things there would be suited to the climate, etc., and enough natural enemies would be present to keep each kind from becoming too numerous.

3. By allowing ladybird beetles, imported originally from Australia, to feed on the scale insects. The beetles are raised especially and shipped to grove owners who release them in the groves, where the beetles feed on the insects.

4. The most important reason is probably that new roads make the streams and lakes more easily accessible to man, who comes in to fish. Unless man is controlled, he removes fish faster than they can reproduce in sufficient numbers to keep up the original number of fish.

As the country becomes built up, lakes and streams may be polluted with industrial wastes, etc., that kill the plants and deprive the fish of a food supply and an oxygen supply, so that fewer fish can be supported.

5. They use the excess water, thus preventing too much from running into the stream. The leaf mold and materials of the forest floor absorb much moisture. The roots of the trees take in a great deal for the use of the tree, and there is very little surface run-off of water in forested regions.

LOOKING BACK AT UNIT 11 (P. 409). For this unit, too, the graph, page 228, may help summarize the main ideas for pupils.

1. Pupils may be expected to give the following big ideas:

a) Each living thing in some way helps other living things.

b) Each living thing is in constant competition with other living things in the struggle to stay alive.
c) All living things depend directly or indirectly upon green plants for food.
d) In nature the supply of raw materials is kept up by decay of the bodies of dead plants and animals and the return of materials to soil and air.
e) Some animals, called social animals, live together in groups and have division of labor.
f) Balance of numbers in nature is obtained when just enough young plants and animals grow up to take the places of ones that die.
g) Man has disturbed the balance of nature by cutting down trees, planting crops, killing animals, etc.

2. A supply of raw materials is kept up in nature by the food *cycle*. Green plants change raw materials from soil and air into food, which is used by other plants and by animals. When plants and animals die, bacteria and other fungi cause them to decay, and the materials go back to the soil and air.

Rotates crops means that a person alternates crops that give nitrogen to the soil with crops that take nitrogen from the soil.

A *colony* is a group of animals or plants of the same kind living together.

Decay is a chemical change brought about by bacteria in which plants and animals are broken up into the many compounds and elements of which they are made.

Nitrates are the compounds of nitrogen that can be used by plants as a source of nitrogen.

The name *legume* is given to plants of the bean family, which includes clover, alfalfa, soy-beans, etc.

A *tubercle* is a small knot, or swelling, on the root of a legume in which live the bacteria that can take nitrogen from the air.

Ecology is the study of the relationships between living things and their surroundings, including other living things.

A *social animal* is one, like a beaver, bee, or ant, that lives and works in a group rather than as an individual.

ADDITIONAL EXERCISES (P. 409). 1. There are valuable suggestions for setting up a terrarium in Turtox Service Leaflet No. 10, "The School Terrarium," and Leaflet No. 23, "Feeding Aquarium and Terrarium Animals," which may be obtained from the General Biological Supply House, 761 East 69th Place, Chicago, Illinois. See Part Four, Publications and Teaching Materials for the Science Teacher, page 255, for other suggestions.

2. In a very dense forest there is not enough light near the forest floor to enable most plants to carry on photosynthesis.

5. Pupils' answers may include any of the following ideas: (a) Much of the bird life of this country has been destroyed:

1) By over-hunting and shooting.
2) By draining swamps, etc., that are the breeding and feeding places of water birds.
3) By cutting off the forests.
4) By plowing up the grasslands.
5) By clean farming, i.e., not leaving long grass and shrubs along fences, etc., around fields.
6) By forest fires that not only kill birds but destroy their nesting places in trees and undergrowth.

b) Some of the methods being used to preserve bird life are:

1) Control of shooting by seasons and licenses.
2) Establishment of refuges for use in breeding and migration where no shooting is allowed.
3) Reflooding of drained areas that are breeding places for ducks, etc.
4) Reforestation.
5) Raising of wild birds by experiment stations.
6) Feeding wild birds during winter when food is scarce.
7) Teaching farmers and gardeners the value of birds as aids in insect and rodent control.

6. This means that he eats and uses both animals and plants for food.

7. Red ants (Lasius americanus) are often in gardens, and black ants (Formica subsericea) near pavements and in fields of woodlands. Many of the nests may be found in excavations under shallow stones. Ant mounds, made of sand, dirt, and bits of plant material and filled with passageways, are common.

By watching closely, differences can be detected in the appearance of ants. The greatest number are small, wingless workers, that act as nurses, housekeepers, soldiers, etc. Some are larger, winged drones, and a few are winged queens, that are much larger than any of the others. The fertilized queens are wingless, but their size and shininess help detect them.

There is much activity in and near an ant nest. Some of the ants seem to run about aimlessly, but others seem engaged in definite activities: carrying bits of food (animal or vegetable matter, seeds, leaf tissue, fungous material), excavating tunnels, caring for young. The latter is the most important duty of the workers; they can often be seen carrying white objects, the pupae, from place to place, presumably to where the conditions for growth are best. When a nest is disturbed, the workers rush to guard the young first. When a nest is destroyed, the ants immediately begin to work on a new one.

8. The class may undertake the preparation of an observation ant nest, which may be kept indefinitely in the laboratory and will be a valuable and interesting project. A demonstration ant nest may be purchased from laboratory supply companies, or one may be constructed with two small panes of glass, some sifted moist soil, and a roll of adhesive tape.

On one pane of glass spread soil a half-inch deep. Lay the second pane on and bind the edges with the tape, leaving an entrance. Place the nest, with some food in it, in a box that is covered to prevent the escape of the ants. In the box place the ant colony with its earth, larvae, and parasites. In a short time the ants will excavate galleries in their new home.

Suggestions for collecting ants and for care of the colony may be found in Turtox Service Leaflet No. 35, "Studying Ants in Observation Nests," published by the General Biological Supply House.

9. The earthworm is called the "living plow" because, as it "eats its way through the earth," it turns over and loosens the soil. It takes in a certain amount of earth and, after getting what food it needs out of it, it excretes the rest in the form of "castings" at the mouth of the burrow. The plowing up of small bits of earth by many earthworms is of great importance in making the soil porous and well aerated.

12. Pupils may list some of these ways in which animals help plants:

a) Provide nitrogenous material for plant fertilizers.
b) Provide means of seed dispersal for many plants.

c) Give off carbon dioxide into the air or water in respiration; this can be used by the plants in photosynthesis.
d) Birds, etc., eat many insects that would destroy the plants.
e) When animals die, their decayed bodies provide the soil with many minerals in addition to nitrogen.
f) Many insects aid plant reproduction by bringing about pollination.
g) The earthworm helps plant growth by keeping the soil loose and porous.

13. Pupils may list some of these ways in which plants are harmful to animals:
a) Some plants (bacteria) cause many diseases in animals.
b) Some plants are poisonous to animals.
c) Some plants, such as the sundew, Venus's-flytrap, etc., use animals for food.
d) Some plants have structures that kill or injure animals that encounter them.
e) Some plants rob man's food plants of materials essential to life, for example, the stem rust fungi on wheat.
f) Other parasitic plants, like mistletoe, rob certain trees of needed food.
g) Some plants may interfere with some of man's activities, e.g., the stopping of drain pipes with plant roots or the filling of waterways with the water hyacinth.

14. No. In a good lawn there is only one kind of plant growing at the expense of all other kinds. It is taking food materials from the soil and not putting much back. Unless man fertilizes the soil, most of the nutrients will be used. If no one cares for the lawn, the grass grows long or is gradually replaced by weeds and other plants that grow naturally in the location. The area returns to a condition in which it is supporting the plants that can exist there in a state of balance. The animal life that was disturbed by the lawn-making also returns.

15. No. The plants that grew there before the garden was plowed up have disappeared, and their places have been taken by many of/fewer kinds of plants. If care is not taken, weeds come in to help make up the original number. The vegetables are used and for the most part removed from the soil. The materials they have taken from the soil must be replaced artificially since

they are not replaced by the dead plants as in a naturally balanced area. The normal animal population has been removed also. If the garden is not cared for, it will return gradually to the natural condition in which a state of balance exists.

16. If left to nature for 100 years, a farm would be well on the way to returning to the wilderness the settlers found. Without man to tend the fields, gardens, and orchards, the native plants would begin to come in to occupy their former area. The animals that were driven out because their homes and feeding places were destroyed would begin to return. Gradually shrubs and then trees would begin to grow. If the area were naturally a forest area, 100 years would probably not see it just as the settlers found it, but it would be well started in that direction. A balance of nature would be restored.

BULLETINS AND PAMPHLETS FOR UNIT 11

Agriculture Miscellaneous Publication
  No. 318. *4-H Club Insect Manual.* 15c
Biological Circular
  No. 61. *Hawks and Owls from the Standpoint of a Farmer.* 5c
Farmers' Bulletins
  No. 513. *Fifty Common Birds of Farm and Orchard.* 25c
  No. 630. *Some Common Birds Useful to the Farmer.* 5c
  No. 1161. *Dodder.* 5c
  No. 1496. *Inoculation of Legumes and Nonlegumes with Nitrogen-Fixing and Other Bacteria.* 10c
  No. 1520. *Soybean Culture and Varieties.* 10c
  No. 1617. *Soybean Utilization.* 5c
  No. 1784. *Nitrogen-Fixing Bacteria and Legumes.* 5c

VISUAL MATERIALS FOR UNIT 11

MOTION PICTURES

Eastman Classroom Films
  "Beavers"
  "The Carbon-Oxygen Cycle"
  "The Nitrogen Cycle"
Erpi Classroom Films, Inc.
  "The Dodder"
  "Plant Traps"

PART THREE

Apparatus and Materials for Experimental Work

The following lists have been prepared to assist teachers in checking their equipment: (1) general lists of laboratory apparatus and materials, tools, and chemicals; (2) lists of laboratory apparatus and materials, chemicals, other apparatus and materials from local stores or home, and living materials needed especially for *Book 1*. They include only the standard apparatus that should be available in science classrooms for the best economy of pupil and teacher time. Much of it can be improvised, or inexpensive substitutes may be arranged where necessary.

Quantities listed provide only for having the experiments done as demonstrations or by one group of students at a time, or are practical minimum amounts for purchase. If a different plan is used, appropriate increases in the quantities should be made. Approximate costs based on prices listed in catalogs of supply companies are given in each list except for those items which may well be obtained free.

The general list includes items which are needed in any science room; practically every item would ordinarily be used in the study of each of the three books. A few of the articles listed are not actually called for in experiments but are almost indispensable. Many will be useful for pupils doing the "Problems to Solve."

There are also practical suggestions for ordering and caring for apparatus and materials and the addresses of some leading scientific supply companies.

1. GENERAL LISTS OF APPARATUS AND MATERIALS

Laboratory Apparatus and Materials

QUANTITY	ITEM	APPROXIMATE COST
1	aquarium, 6-gal.	$6.00
1	aquarium dip net	.20
1	balance, spring, graduated in ounces and grams	.65
6	beakers, Pyrex, 250 or 350 cc.	1.20
6	bottles, wide-mouth, 8 oz.	.43
1	burner, Bunsen (if gas is available; otherwise some satisfactory source of heat)	.50
12	candles, paraffin	.25
2	clamps, burette, single, adjustable	.60
2	clamps, right-angle	.50
1 bag	corks, assorted, some ordinary shapes, some flat	.55
1	cylinder, graduated, glass, 100 cc.	.85
4	dry cells	1.20
2	evaporating dishes, porcelain, 3 in. (75 mm.) dia. or larger	.36
1 box	filter paper (100 circles), 12 cm. dia.	.16
2	flasks, Pyrex, Erlenmeyer, 300 cc. or larger	.44
6	flower pots, medium size	.50
1	funnel, glass, 3 in. (75 mm.) dia.	.28
2	glass plates, 12 x 12 in. (to cover jars and pans)	.80
3	glass plates, 3 x 3 in.	.12
1 lb.	glass tubing, 3-4 mm. outside dia.	.60
1 lb.	glass tubing, 6 mm. outside dia.	.90
18 in.	glass tubing, 18 mm. outside dia.	.12
1	jar, glass, 1 qt.	.45
1	jar, glass, 2 qt.	.65
1	lamp chimney, ordinary	.25
1	lodestone	.25
2	magnets, bar (may well be rod-shaped cobalt-chrome)	.80
1	magnet, horseshoe, large (or U-magnet)	.18

QUANTITY	ITEM	APPROXIMATE COST
1	magnifier, tripod	.75
1	medicine dropper	.05
1	microscope, compound	65.80
½ oz.	microscope cover glasses	.33
½ gross	microscope slides, glass	.60
1 doz.	needles, steel knitting	.30
2	pans, round, flat, enamel, 2 qt. or larger	.60
1	pump, bicycle, hand pressure	.50
1	reading-glass, or other large convex lens	1.00
2	ringstands, with small, medium, and large rings	2.10
6	rubber stoppers, No. 2, 1-hole	.12
6	rubber stoppers, No. 6, 1-hole	.30
6	rubber stoppers, 1-hole, to fit wide-mouth bottles	.36
6	rubber stoppers, 2-hole, to fit wide-mouth bottles	.36
6 ft.	rubber tubing, 5/16 in. inside dia. (for connecting burner)	.72
6 ft.	rubber tubing, 3/16 in. inside dia.	.48
10 lb.	sand, for aquarium	.50
2	stirring rods, glass, 8 in. x 3/16 in. dia.	.20
24	test-tubes, ordinary glass, 6 x ¾ in.	.60
2	test-tubes, Pyrex, 6 x ¾ in.	.10
1	test-tube brush	.10
3	test-tube holders	.30
1	test-tube rack	.40
2	thermometers, chemical 10-110° C. (double-scale graduated also on Fahrenheit)	2.40
1	trip scales, with 1 set brass weights—1-500 gm.	10.80
6	tumblers, glass	.60
¼ lb.	wire, iron, bare, No. 22 or 24	.13
1 spool	wire, iron, No. 30	.30
2 lb.	wire, copper, double cotton-covered, No. 18 or 22	1.80
2	wire gauze, iron, 6 x 6 in.	.20
		$112.69

TOOLS

QUANTITY	ITEM	APPROXIMATE COST
1 set	auger bits, 1 each, ¼, ½, 1 in.	$1.60
1	brace	1.50
1	file, round, small (4-in.)	.15
1	file, triangular, 4-in. or 6-in.	.12
1	forceps, steel or brass	.15
1	hammer, claw type	.25
1	knife, paring or large pocket-size	.35
2	needles, dissecting	.10
1	pliers, 6-in., wire cutting	.30
1	scalpel	.35
1	scissors, small, slender	.45
1	screw-driver, 4-in. blade	.25
1	shears, strong	1.00
1	trowel or spade	.30
		$6.87

CHEMICALS

QUANTITY	ITEM	APPROXIMATE COST
1 lb.	acid, hydrochloric, concentrated	$0.52
1 lb.	acid, nitric, concentrated	.54
1 lb.	acid, sulphuric, concentrated	.52
1 pt.	alcohol, denatured	.30
1 lb.	ammonium hydroxide, technical	.51
1 lb.	calcium oxide (for making limewater)	.30
1 lb.	copper (cupric) sulphate, technical	.30
1 cube	gum camphor	.30
4 oz.	iodine, Lugol's solution (to be diluted)	.40
1 lb.	potassium nitrate	.30
1 lb.	sodium bicarbonate (baking soda)	.20
1 lb.	sodium chloride (table salt)	.20
1 lb.	starch, laundry	.20
		$4.59

2. LISTS OF APPARATUS AND MATERIALS NEEDED ESPECIALLY FOR BOOK I

LABORATORY APPARATUS AND MATERIALS

QUANTITY	ITEM	APPROXIMATE COST
2	jars, stoneware, 2-gal. with covers (may be used for waste when not needed for experiments) .	$2.50
1	lamp, kerosene	.50
1 pkg.	needles, sewing, large	.10
1	plate, brass, 6 x 6 in., 22 or 24 gauge	.20
1	plate, copper, 6 x 6 in., 22 or 24 gauge	.20
1	plate, zinc, 6 x 6 in., 22 or 24 gauge	.20
1 pkg.	razor blades, safety, single-edge	.50
1	sheet iron or "tin" plate, 6 x 6 in.	.10
1 doz.	vials, glass, homeopathic	.15
		$4.45

CHEMICALS

QUANTITY	ITEM	APPROXIMATE COST
¼ lb.	acid, citric	$0.25
1 lb.	calcium chloride	.23
¼ lb.	calcium sulphate, C.P.	.26
1 lb.	carbon tetrachloride (or Carbona cleaning fluid)	.32
4 oz.	Fehling's solution A	.25
4 oz.	Fehling's solution B	.30
1 lb.	iron filings	.20
1 lb.	iron powder	.30
1 oz.	magnesium powder	.30
¼ lb.	magnesium ribbon, 1 oz. rolls	1.40
¼ lb.	mercuric oxide	.57
1 oz.	pepsin, dry	.35
1 oz.	silver nitrate, C.P. crystals	.60
1 lb.	sulphur, powdered	.20
		$5.53

OTHER APPARATUS AND MATERIALS FROM LOCAL STORES OR HOME

QUANTITY	ITEM
1 pkg.	absorbent cotton
1 piece	aluminum (cut from old utensil)
2	asbestos pads
1 doz.	blotting-papers
1 piece	board, 1 ft. sq.
2	bricks
4 pieces	cardboard, 1 ft. sq.
1	cardboard tube, ½ in. dia.
1 piece	celluloid
1 yd.	cheesecloth, fine
1 piece	clock spring
1 piece	cloth, silk, 6 x 6 in.
1 piece	cloth, wool, 6 x 6 in.
	coal, soft
1	dish with tight lid (p. 330)
1	dish, white
1 qt.	distilled water
1	football or basketball
1 pt.	gasoline
2	handkerchiefs, same size and material
1 bottle	ink, fountain-pen
1 bottle	ink, red
1 qt.	kerosene
1 pkg.	labels, gummed
1 lump	limestone
1 lump	marble
1 carton	matches, safety
1	milk bottle, qt.
few	nails, large

QUANTITY	ITEM
1 pt.	paint, any kind
1	paint brush, small
	paper, black
	paper, stiff white
	paper toweling
few	pen points
1 pkg.	pins, common
several	punk sticks
1 box	rubber bands, assorted
1 tube	rubber cement
1	ruler
1 qt.	sand
1	sponge
	steel wool, bright
several	stones, small
1 ball	string
½ lb.	sugar
1 box	tacks, carpet, iron
	tea leaves
1 spool	thread, cotton
1 spool	thread, silk
1 box	thumb tacks
several	tin-can lids
1	tin cup, bright
	tin-foil
1 box	toothpicks
1 pt.	turpentine
1 roll	waxed paper
pieces	wood, small
several	wood (pine) splinters
1	wooden support for magnets (pp. 234, 244 of text)

MATERIALS TO BE OBTAINED WHEN NEEDED

(Because of the perishable nature of many of these items, they should be obtained a short time before they are needed. Page references to the text are given to indicate exactly when they will be required.)

QUANTITY	ITEM
1 culture	amoeba for 10-25 pupils (p. 287). Approx. $2.50
several	animals for aquarium—snails, 12 for 40c; tadpoles, 12 for 50c; fish—mud minnows or catfish or sticklebacks, 1 pr. for 75c; fresh-water clam, 25c each (p. 403)
several	animals for observation in science room—toads, 75c each; frogs, 35c each; caterpillars, grasshoppers, crickets, crayfish, 20c; chameleon, 40c; turtles, 25c-$1.25 (p. 301)
	apple (p. 284)
slices	bread (p. 330)
	carnation, white, or daffodil (p. 320)
	celery stalk (pp. 284, 320)
	corn stalk, dry (p. 321)
can	corn syrup (p. 360)
	egg (p. 344)
	fish food (p. 403)
	geranium plant (pp. 324, 325)
	ice (p. 138)
	lard or butter (p. 98)
	maple twig (pp. 284, 320)
1	nasturtium plant (p. 325)
few	onions (pp. 287, 324)
	plant, potted—begonia, geranium (p. 273)
	potato, Irish (p. 161)
	seeds for germination (radish or mustard or cabbage) (p. 317)
several	slides, prepared, of animal tissue—epidermis of frog, 60c; brain or spinal cord, 50c; lining of large intestine or stomach, 50c; blood of frog or bird, 50c (p. 285)
	soil (p. 273)
	tomato (p. 284)
2 oz.	vinegar (p. 221)
1 set	water plants (Vallisneria, Sagittaria, Elodea, Myriophyllum) (p. 403). Approx. $1.25

3. SUGGESTIONS FOR ORDERING AND CARING FOR APPARATUS AND MATERIALS

In equipping the laboratory much depends on local conditions and available funds. No teacher of introductory science should feel it necessary to have a large appropriation for apparatus and materials. He will find available in other science laboratories many materials that he can borrow, and his students will gladly help him bring to the laboratory from home and neighborhood stores a considerable portion of the necessary supplies. It is only essential to plan far enough in advance for the experimental work and then proceed to use to the best advantage such supplies as are available through purchase, through loan by other science teachers, and through the teacher's ingenuity and pupils' assistance.

If the apparatus and materials are properly cared for, and if pupils take pride in helping to provide essential materials, the store of equipment may be built up within a few years. Some materials must be purchased, of course, but there are ways to raise the necessary funds even if the school appropriation is smaller than the amount needed.

ORDERING APPARATUS AND MATERIALS

In ordering supplies it is first necessary to survey the course to be taught and then to select that material which appears to be most fundamental to the proper study of the course. The lists that are given represent these fundamental materials for *Science Problems, Book 1.*

The next step is to submit copies of your list of necessary materials to three or four of the leading laboratory supply companies for an estimate. This step applies, of course, to those articles that cannot be obtained from home or from neighborhood stores. A list of companies is given on page 253. Catalogs (that may be had on request) from two or three of the nearest supply houses may profitably be consulted in making your list.

When the estimates are received, the next step is to place the order in whole or in part with the company (or companies) that furnishes the best estimate on the entire order or on any items of the order. Having the catalogs of the companies at hand, it will be easy to look up the specifications of any item that they quote.

In places where the teacher does not find it possible or practicable to proceed as suggested, the list may be sent to the purchasing agent or principal, who will forward it to the supply companies.

If a card index is kept for all equipment, it will be an easy matter to know at any time what equipment and supplies are on hand and also to make out the order for the next year. Some teachers prefer to keep a notebook list of supplies on hand. Such a list is not as flexible or as handy as an alphabetical card index.

Bar magnets	C.A. Co. Cat. No. 48	Case 8 Shelf C

Date	On Hand	Ordered	No.	Price	Remarks
10/1/41	2	2/1/39	2	.80	Loaned to Mr. Thomas 1/15/40 Returned 2/12/40

FIG. 17. FORM FOR LABORATORY INDEX CARD

The authors have found that a card index of apparatus and materials is a great convenience in ordering and in making the annual inventory. Furthermore, such a card index is a permanent part of the laboratory, and a new teacher may quickly familiarize himself with the apparatus on hand and its location. The form of card found most useful is shown in Figure 17. Pupils will gladly help in ruling the cards; they may be prepared from a stencil, or the school printing class may make them. The 4 x 6 size has been found to be most satisfactory.

Such a card may contain an exact description of the article with a reference to catalog number or letter of a laboratory supply company, as well as the price, as indicated on the form shown (p. 252). With the item once entered on the card, it is not necessary to turn to the catalog every time a new order is to be placed. It is only necessary to leaf through the cards as the inventory is made, enter the number or quantity on hand, and if an additional supply is needed, make proper entry in the columns for that purpose. Any secretary or pupil can then take the cards and make up a list of items to be ordered. If prices are entered on the cards, queries from the principal or superintendent concerning the value of apparatus and materials on hand may be quickly and accurately answered.

CARING FOR APPARATUS AND MATERIALS

If enough cabinet space is available, the authors have found the following plans and practices of value:

a) Store all "chemicals" and other materials in alphabetical order.

b) Store assembled apparatus used with particular units in groups by units.

c) Have such commonly used apparatus as test-tubes, Bunsen burners, and matches near or on the demonstration table.

d) If apparatus is out of order, do not put it away until it is repaired.

e) Have pupils acquainted with the plan of storing apparatus so that they will not waste time in getting it and so that it will always be returned to the proper place.

f) Number the sections of cabinets and cases in order.

4. SCIENTIFIC SUPPLY COMPANIES

Biological Supply Co., 1176 Mt. Hope Ave., Rochester, N. Y.
California Biological Service, 1612 W. Glenoaks Blvd., Glendale, Calif. (Soilless plant culture)
Cambridge Botanical Supply Co., Waverley, Mass.

Carolina Biological Supply Co., Elon College, N. C.
Central Scientific Co., 1700 Irving Park Blvd. (Lakeview Station), Chicago, Ill.; 220 E. 42d St., New York, N. Y.; 1121 S. Hill St., Los Angeles, Calif.; 79 Amherst St., Boston, Mass.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago, Ill.
Clay-Adams Co., 25 E. 26th St., New York, N. Y. (Models and charts)
Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago, Ill. (Models and charts)
Empire Laboratory Supply Co., 507-559 W. 132d St., New York, N. Y.
General Biological Supply House, 761-763 E. 69th Place, Chicago, Ill.
Heil Corp., 210 S. Fourth St., St. Louis, Mo.
Kny-Scheerer Corp., 21-09 Borden Ave., Long Island City, N. Y.
Marine Biological Laboratory, Woods Hole, Mass.
Michigan Biological Supply House, 206 S. First St., Ann Arbor, Mich.
Millard Heath Co., 400 N. 3d St., St. Louis, Mo.
New York Biological Supply Co., 34 Union Square, New York, N. Y.
A. J. Nystrom and Co., 3333 Elston Ave., Chicago, Ill. (Charts)
Oregon Biological Supply Co., 1806 S. E. Holgate Blvd., Portland, Ore.
Scientific Supplies Co., 123 Jackson Ave., Seattle, Wash.
Southern Biological Supply Co., 517 Decatur, New Orleans, La.
Standard Scientific Supply Corp., 12 W. 25th St., New York, N. Y.
University Apparatus Co., 2229 McGee Ave., Berkeley, Calif.
Wards Natural Science Establishment, 302 N. Goodman, Rochester, N. Y.
W. M. Welch Scientific Co., 1515 N. Sedgwick St., Chicago, Ill.
Western Laboratories, 826 Q St., Lincoln, Nebr.

PART FOUR

Publications and Teaching Materials for the Science Teacher

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1. READING AND REFERENCES

GENERAL READING ON THE TEACHING OF SCIENCE

Croxton, W. C. *Science in the Elementary School.* New York: McGraw-Hill Book Co., 1937.

Curtis, F. D. A Digest of Investigations in the Teaching of Science. Philadelphia: P. Blakiston's Son & Co., 1925.

Curtis, F. D. *A Second Digest of Investigations in the Teaching of Science.* Philadelphia: P. Blakiston's Son & Co., 1931.

Curtis, F. D. *A Third Digest of Investigations in the Teaching* of Science. Philadelphia: P. Blakiston's Son & Co., 1939.

Downing, E. R. *An Introduction to the Teaching of Science* (a revision of *Teaching Science in the Schools*). Chicago: University of Chicago Press, 1934.

Mayfield, John C., Parker, Bertha M., Blough, Glenn O. *Science Instruction in Elementary and High School Grades.* Chicago: University of Chicago Press, 1939.

Miller, David F., and Blaydes, Glenn W. *Methods and Materials for Teaching Biological Sciences.* New York: McGraw-Hill Book Co., 1938.

National Society for the Study of Education, Thirty-first Yearbook, Part I. *A Program for Teaching Science.* Bloomington, Ill.: Public School Publishing Co., 1932.

Noll, Victor H. *The Teaching of Science in Elementary and Secondary Schools.* New York: Longmans, Green, 1939.

Palmer, E. Laurence. *Nature Magazine's Guide to Science* Teaching. Washington, D. C.: American Nature Association, 1936.

Preston, Carleton E. *The High School Science Teacher and His Work.* New York: McGraw-Hill Book Co., 1936.

Progressive Education Association. *Science in General Education.* New York: D. Appleton-Century Co., 1938.

Science Instruction and America's Problems. Washington, D.C.: Department of Science Instruction of the N. E. A., 1940.

Skinner, Charles E. (ed.) *Educational Psychology.* New York: Prentice-Hall, Inc., 1936.

Slavson, S. R., and Speer, R. K. *Science in the New Education.* New York: Prentice-Hall, 1934.

Underhill, O. E. *The Origins and Development of Elementary-School Science.* Chicago: Scott, Foresman and Co., 1941.

Reading on Various Aspects of Science Teaching

The American Institute of the City of New York, 310 Fifth Ave., New York, N. Y., is organized to direct and utilize the imaginative faculties of youth. It has 730 juvenile clubs under its wings. Write to it for information about science clubs.

Atyeo, Henry C. *The Excursion as a Teaching Technique.* New York: Bureau of Publications, Teachers College, Columbia University, 1939.

Cook, Dorothy E., and Rahbek-Smith, Eva. *Educational Film Catalog.* New York: H. W. Wilson Co., 1939.

Exelby, C. L., and Gambill, L. B. *Science Club Manual.* Lansing, Mich.: The National Club Manual Co., 1931.

Harrison, Margaret. *Radio in the Classroom.* New York: Prentice-Hall, 1937.

Heiss, E. D., Obourn, E. S., and Hoffman, C. W. *Modern Methods and Materials for Teaching Science.* New York: The Macmillan Co., 1940.

Hoban, Charles F., Hoban, Charles F., Jr., and Zisman, Samuel B. *Visualizing the Curriculum.* New York: Cordon Co., 1937.

Hurley, Richard James. *Key to the Out-of-Doors.* New York: H. W. Wilson Co., 1938. (Lists books, films, slides, etc.)

Laine, Elizabeth. *Motion Pictures and Radio: Modern Technique for Education.* New York: McGraw-Hill Book Co., 1938.

Moore, E. M. *Youth in Museums.* Philadelphia: University of Pennsylvania Press, 1941.

Ramsey, Grace F. *Educational Work in Museums of the United States.* New York: H. W. Wilson Co., 1938.

Ruch, G. M. The Objective or New-Type Examination. Chicago: Scott, Foresman and Co., 1929.

Towne, Mary E. *Teaching with Motion Pictures: A Guide to Sources of Information and Materials.* Teachers College Library Contributions, No. 1. New York: Teachers College, Columbia University, 1940.

Turtox Service Leaflets, Turtox Teacher's Manual. Chicago: General Biological Supply House. Free.

Vinal, W. G. *Nature Recreation;* group guidance for the out-of-doors. New York: McGraw-Hill Book Co., 1940.

Wood, B., and Freeman, F. N. *Motion Pictures in the Classroom.* Boston: Houghton Mifflin Co., 1929.

Woodring, M. N., Oakes, M. E., and Brown, H. E. *Enriched Teaching of Science in the High School.* New York: Bureau of Publications, Teachers College, Columbia University, 1928. (Lists available free materials.)

REFERENCE BOOKS

Many of these books are surveys of important departments of science or of the whole science field. Non-technical in style, they are designed to broaden the reader's background of information and increase his insight into the significance of science.

Allee, Warder C. *The Social Life of Animals.* New York: W. W. Norton and Co., 1938.

Bond, Phyllis. *Watching Wild Life.* New York: Longmans, Green & Co., 1937.

Borsook, Henry. *Vitamins: What They Are and How They Can Benefit You.* New York: Viking Press, 1940.

Buchsbaum, Ralph. *Animals without Backbones.* Chicago: University of Chicago Press, 1938.

Chamberlain, Charles J. *Elements of Plant* Science. New York: McGraw-Hill Book Co., 1930.

Collingwood, G. H. *Knowing Your Trees.* Washington, D. C.: American Forestry Association, 1937.

Coulter, Merle C. *The Story of the Plant Kingdom.* Chicago: University of Chicago Press, 1936.

Cressy, Edward. *Discoveries and Inventions of the Twentieth Century.* New York: E. P. Dutton Co., 1930.

Croneis, Carey, and Krumbein, William C. *Down to Earth.* Chicago: University of Chicago Press, 1936.

Curie, Eve. *Madame Curie: A Biography.* New York: Doubleday Doran and Co., 1937.

Fairchild, David G. The World Was *My Garden.* New York: Charles Scribner's Sons, 1938.

Findlay, Alexander. *A Hundred Years of Chemistry.* New York: The Macmillan Co., 1937.

Furnas, C. C. *The Next Hundred Years.* New York: Blue Ribbon Books, 1938.

Hylander, Clarence J. *Plants and Man.* Philadelphia, Pa.: The Blakiston Co., 1941.

Jacobs, Morris J. *The Chemical Analysis of Foods and Food Products.* New York: D. Van Nostrand Co., 1938.

The Layman Scientist in Philadelphia. Edited by W. Stephen Thomas. Committee on Education and Participation in Science. Philadelphia, Pa.: American Philosophical Society.

Lemon, Harvey B. *From Galileo to Cosmic Rays.* Chicago: University of Chicago Press, 1935.

Lynde, C. J. *Science Experiments with Home Equipment.* Scranton, Pa.: International Textbook Co., 1937.

Lynde, C. J. *Science Experiments with Inexpensive Equipment.* Scranton, Pa.: International Textbook Co., 1939.

Matlin, D. R. *Growing Plants Without Soil.* New York: Chemical Pub. Co., 1940.

Orientation in Science. By eleven members of the University of Rochester faculty. Edited by C. W. Watkeys. New York: McGraw-Hill Book Co., 1938.

Outline of Science, The. Edited by J. Arthur Thomson. New York: G. P. Putnam's Sons, 1937.

Pfeiffer, John. Science in Your Life. New York: The Macmillan Co., 1939.

Richards, Harold. *The Universe Surveyed.* New York: D. Van Nostrand Co., 1937.

Robbins, William J., and Rickett, Harold W. *Botany.* New York: D. Van Nostrand Co., 1934.

Snell, Foster Dee and Cornelia T. *Chemicals of Commerce.* New York: D. Van Nostrand Co., 1939.

Wells, H. G., and Huxley, Julian S. *The Science of Life.* New York: Doubleday, Doran and Co., 1934.

World and Man As Science Sees Them. By twelve members of University of Chicago faculty. Edited by Forest Ray Moulton. Chicago: University of Chicago Press, 1937.

PUBLISHERS' NAMES AND ADDRESSES

American Forestry Association, 919 Seventeenth St., N. W., Washington, D. C.

American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.

American Philosophical Society, 104 S. 5th Street, Philadelphia, Pa.

D. Appleton-Century Co., 35 W. 32d St., New York, N. Y.

P. Blakiston's Son & Co. (now The Blakiston Co.), 1012 S. Walnut St., Philadelphia, Pa.

Blue Ribbon Books, 386 Fourth Ave., New York, N. Y.

Chemical Publishing Co., 148 Lafayette St., New York, N. Y.

Columbia University (Bureau of Publications, Teachers College), New York, N. Y.

The Cordon Co., Inc., New York, N. Y. (Its publications have been acquired by The Dryden Press, Inc., 103 Park Ave., New York, N. Y.)

Doubleday, Doran and Co., 14 W. 49th St., New York, N. Y.

E. P. Dutton Co., 286 Fourth Ave., New York, N. Y.

Ginn and Co., 20 Providence St., Boston, Mass.

Houghton, Mifflin and Co., 2 Park St., Boston, Mass.

International Textbook Co., 1001 Wyoming Ave., Scranton, Pa.

Longmans, Green & Co., 55 Fifth Ave., New York, N. Y.

McGraw-Hill Book Co., 330 W. 42d St., New York, N. Y.

The Macmillan Co., 60 Fifth Ave., New York, N. Y.
National Education Association, 1201 Sixteenth St., N. W., Washington, D. C.
W. W. Norton and Co., 70 Fifth Ave., New York, N. Y.
Prentice-Hall, 70 Fifth Ave., New York, N. Y.
Public School Publishing Co., 509-513 N. East St., Bloomington, Ill.
G. P. Putnam's Sons, 2 W. 45th St., New York, N. Y.
Scott, Foresman and Co., 623 S. Wabash Ave., Chicago, Ill.
Charles Scribner's Sons, 597 Fifth Ave., New York, N. Y.
University of Chicago Press, 5750 Ellis Ave., Chicago, Ill.
University of Pennsylvania Press, 3622 Locust St., Philadelphia.
D. Van Nostrand Co., 250 Fourth Ave., New York, N. Y.
Viking Press, 18 E. 48th St., New York, N. Y.
The H. W. Wilson Co., 950 University Ave., New York, N. Y.

2. PERIODICALS FOR TEACHERS AND PUPILS

(Starred [*] publications are suitable for pupils.)

The American Biology Teacher, published by The National Association of Biology Teachers, N. Queen St. and McGovern Ave., Lancaster, Pa. (Monthly from October to May. Annual membership in The National Association of Biology Teachers, including subscription, $1.00.)

**American Forests,* published by The American Forestry Association, 919 Seventeenth St., Washington, D. C. (Monthly. $4.00 a year; 35c a copy.)

**Audubon Magazine,* formerly *Bird Lore,* published by The National Association of Audubon Societies, Crescent and Mulberry Sts., Harrisburg, Pa. (A bi-monthly magazine devoted to the study and protection of birds and mammals. $1.75 a year; 30c a copy.)

**Building America,* published for The Society for Curriculum Study, 140 N. 6th St., Philadelphia, Pa. Distributed by the Americana Corporation, 2 W. 45th St., New York, N. Y. (Monthly from October through May. $2.00 for single set of 8 units; 30c a single copy.)

Consumers' Guide, published by the Department of Agriculture, Washington, D. C. (Monthly from June through September; semi-monthly from October through May. 50c a year; 5c a copy.)

*Current Science, published by American Education Press, Inc., 400 Front St., Columbus, Ohio. (Weekly during school; 75c a year.)

**Frontiers*, A Magazine of Natural History, published by The Academy of Natural Sciences of Philadelphia, 19th St. and The Parkway, Philadelphia, Pa. (Five times a year—October, December, February, April, June. $1.00 a year; 25c a copy.)

Hygeia, The Health Magazine, published by The American Medical Association, 535 N. Dearborn St., Chicago, Ill. (Monthly. $2.50 a year; 25c a copy.)

Journal of Chemical Education, official publication of The Division of Chemical Education of the American Chemical Society, 20th and Northampton Sts., Easton, Pa. (Monthly. $3.00 a year; 50c a copy.)

**The Junior Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Monthly. $1.00 a year.)

**The National Geographic Magazine*, published by The National Geographic Society, 16th and M Sts., N. W., Washington, D. C. (Monthly. Annual membership in The National Geographic Society, including subscription, $3.50.)

**Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Monthly except July and August. $3.00 a year; 50c a copy.)

**Nature Magazine*, published by the American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C. (Monthly. $3.00 a year; 35c a copy.)

**Nature Notes*, The Magazine of Outdoor Information, 4800 Prospect Road, Peoria, Ill. (Monthly. $1.00 a year; 15c a copy.)

Peabody Journal of Education, published by George Peabody College for Teachers, Nashville, Tenn. The July issue of each year contains Mr. H. A. Webb's "High School Science Library" for the preceding twelve months. (Monthly. $2.00 a year; 40c a copy.)

**Popular Mechanics*, 200 E. Ontario St., Chicago, Ill. (Monthly. $2.50 a year, $4.00 for two years; 25c a copy.)

**Popular Science Monthly*, published by Popular Science Publishing Co., Inc., 353 Fourth Ave., New York, N. Y. (Monthly. $1.50 a year; 15c a copy.)

**School Nature League Bulletin*, published by the School Nature League, Inc., 79th St. at Central Park West, New York, N. Y. (Monthly, from September through June. 50c a year.)

School Science and Mathematics, publication of the Central Association of Science and Mathematics Teachers, Inc. Published at 450 Ahnaip St., Menasha, Wis. (Monthly except July, August, and September. $2.50 a year; 35c a copy.)

**Science Digest*, published by Science Digest, Inc., 631 St. Clair St., Chicago, Ill. (Monthly, $2.50 a year; 25c a copy.)

Science Education, the official organ of the National Association for Research in Science Teaching, the National Council on Elementary Science, and the Science Association of the Middle States. Published by Science Education, Inc., 374 Broadway, Albany, N. Y. (Seven times a year. $2.50 a year; 50c a copy.)

Science News Letter, The Weekly Summary of Current Science, published by Science Service, Inc., 1719 N Street, N. W., Washington, D. C. (Weekly. $5.00 a year, $7.00 for two years; 15c a copy.)

Science Observer, published by The American Institute of the City of New York, 60 E. 42d St., New York, N. Y. (Monthly during the school year. 50c a year for one subscription; 45c a year for ten or more to one address. 5c a copy; 4½c in lots of ten or more; 4c in lots of twenty or more.)

The Scientific Monthly, publication of The American Association for the Advancement of Science, Smithsonian Institution Building, Washington, D. C. Published by The Science Press, Lancaster, Pa. (Monthly. $5.00 a year; 50c a copy.)

3. OTHER MATERIALS FOR TEACHING SCIENCE

SOURCES OF INFORMATION

This section gives a list of organizations and agencies from which teachers can secure reliable information on various science problems, either free or at a nominal cost. These organizations include commercial companies, scientific societies, museums, and state and United States Government departments and bureaus. Much information on specific problems can be secured also from the community in which one lives.

COMMERCIAL ORGANIZATIONS

Bausch and Lomb, Rochester, N. Y.
Eastman Kodak Company, Rochester, N. Y.
General Electric Company, Schenectady, N. Y.
General Motors Corporation, Research Division, Detroit, Mich.
Metropolitan Life Insurance Company, New York, N. Y.
Taylor Instrument Company, Rochester, N. Y.

MISCELLANEOUS ORGANIZATIONS

American Association for the Advancement of Science, Smithsonian Institution, Washington, D. C.
American Chemical Society, Mills Building, Washington, D. C.
American Forestry Association, 919 Seventeenth St., Washington, D. C.
American Home Economics Association, 620 Mills Building, Washington, D. C.
American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.
American Wild Life Institute, Investment Building, Washington, D. C.
National Academy of Science, Washington, D. C.
National Board of Fire Underwriters, 58 John St., New York, N. Y.

National Parks Association, 1624 H St., N. W., Washington, D. C.
Science Service, 2101 Constitution Ave., Washington, D. C.
Smithsonian Institution, Washington, D. C.

MUSEUMS

American Museum of Natural History, New York, N. Y.
Carnegie Institute Museum, Washington, D. C.
Chicago Zoölogical Park, Brookfield, Ill.
Field Museum of Natural History, Chicago, Ill.
Museum of Science and Industry, Chicago, Ill.
Museum of Science and Industry, Rockefeller Center, New York, N. Y.
National Academy of Sciences, Washington, D. C.
National Zoölogical Gardens, Washington, D. C.
New York Botanical Gardens, New York, N. Y.
New York Zoölogical Society, New York, N. Y.

STATE DEPARTMENTS

Agriculture, Fisheries, Forests and Waters, Health, Highways

U. S. GOVERNMENT DEPARTMENTS AND BUREAUS

A list of the publications of these departments and bureaus may be secured from the Superintendent of Documents, Washington, D. C.

SOURCES OF MOTION-PICTURE FILMS

American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Rents films on hygiene, domestic science, biology, general science, physics, chemistry.)
Bausch & Lomb Optical Company, Rochester, N. Y. (Free through local B & L dealers)
Bell & Howell Co., 1801-15 Larchmont Ave., Chicago, Ill. (Sells or rents biological or scenic films.)
Caravel Films, Inc., 245 W. 55th St., New York, N. Y. (Free films on science subjects)

Frank R. Church Films, 829 Harrison Ave., Oakland, Calif. (Sells or rents wild life, industrials, and science subjects. Some are free.)

Commercial Motion Picture Productions, 8634 Sunset Blvd., Hollywood, Calif. (To sell)

Du Pont Company, Motion Pictures Bureau, Wilmington, Del. (Free)

Eastman Classroom Films, Teaching Films Division, Eastman Kodak Co., Rochester, N. Y. (To sell)

Edited Pictures System, Inc., 330 W. 42d St., New York, N. Y. (Sells or rents scientific films.)

Erpi Classroom Films Inc., 35-11 35th Ave., Long Island City, N. Y. (For sale or rent through University of Chicago Press, 5750 Ellis Ave., Chicago, Ill.; also may be rented through some University Bureaus of Visual Instruction.)

General Electric Company, Visual Instruction Section, 1 River Road, Schenectady, N. Y. (Rent or free)

Harvard Film Service, The Biological Laboratories, Cambridge, Mass. (Sell or rent sound and silent science subjects.)

International Education Pictures, Inc., 40 Mt. Vernon St., Boston, Mass. (Sell or rent; some are free.)

Kodascope Library, 33 W. 42nd St., New York. (Sell or rent.)

Motion Picture Bureau of the Y. M. C. A., 347 Madison Ave., New York, N. Y., or 19 S. La Salle St., Chicago (Sound or silent films to rent or free)

Pyrene Manufacturing Co., Sales Promotion Department, 560 Belmont Ave., Newark, N. J. (Free)

School Films Service, Inc., 55 W. 42d St., New York, N. Y. (Sell or rent science films.)

Society for Visual Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)

Swift & Co., Public Relations Department, Union Stock Yards, Chicago, Ill. (Free)

U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa. (Free)

U. S. Department of Agriculture, Extension Service, Office of Motion Pictures, Washington, D. C. (Free)

The U. S. Office of Education has compiled lists of available films.

Wild Flowers Preservation Society, 3740 Oliver St., N. W., Washington, D. C. (Sell or rent)

A mimeographed booklet, distributed by the Photographic Section of the Division of Information, U. S. Department of the Interior, Washington, D. C., lists eighty-nine films with brief annotations. Many of these are of science interest. These may be borrowed.

Many state universities have bureaus of visual instruction that have a large supply of films to be rented. It will be worthwhile for a teacher to request a catalog from the bureau in his state. Many of them rent to neighboring states also.

SOURCES OF SLIDES AND FILMSTRIPS

Bray Pictures Corporation, 130 W. 47th St., New York, N. Y.

Chicago Academy of Science, Chicago, Ill. (Commercial slides)

General Biological Supply House, 761 E. 69th Place, Chicago, Ill.

General Electric Company, Motion Picture Division, Schenectady, N. Y. (Commercial slides)

Keystone View Company, Meadville, Pa.

National Association of Audubon Societies, Crescent and Mulberry Sts., Harrisburg, Pa.

National Park Service, Department of Interior, Washington, D. C.

Society for Visual Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)

Spencer Lens Company, Buffalo, N. Y.

State Museums. Many lend slides to teachers within their state.

Stillfilm, Inc., Hollywood, Calif.

United States Department of Agriculture, Washington, D. C.

Visual Education Service, Inc., 7024 Melrose Ave., Los Angeles, Calif.

Visual Text Sales Company, Los Angeles, Calif.

BASIC STUDIES IN SCIENCE

TEACHER'S GUIDEBOOK

for SCIENCE PROBLEMS

BOOK 2

by

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Chicago, Atlanta, Dallas, New York

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Preface

The three books of the *Science Problems* series have been written specifically for science reading and science instruction in the seventh, eighth, and ninth grades of American schools. This *Guidebook* is intended to assist administrators and teachers in making the most effective use of the series, and specifically of *Book 2*, by stating the authors' point of view on: (1) the objectives of science instruction at this level; (2) the principles and plan of organization of the series; (3) suggestions for fitting the course to local conditions; (4) the general technique of effective instruction in science; and (5) the principal types of difficulties that pupils meet in their study of science.

The *Guidebook* furnishes detailed helps for teaching each unit and includes correct responses for the exercises. These helps are planned especially for the busy teacher, to relieve him of some of the mechanical labor incident to teaching any course and to make clear the authors' aims and method. Neither this nor any teacher's manual can be a panacea for all teaching difficulties, nor should such a manual interfere with the initiative and individuality of the teacher.

The inexperienced teacher will find this *Guidebook* particularly helpful. The experienced teacher will find in it many suggestions which have come out of actual classroom situations. These he will modify and supplement from his own experiences. If the suggestions serve to assist in modifying the lives of pupils through the development of their intellectual powers and through the acquisition of worth-while knowledge, thus insuring that the pupils will better adjust themselves to their environment and control it, the time and effort spent in the preparation of this guide will have been justified. The authors will be most grateful for any suggestions which teachers may wish to offer and which may be included when the *Guidebook* is revised.

Wilbur L. Beauchamp
John C. Mayfield
Joe Young West

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PART ONE

General Considerations

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1. INTRODUCTION

The formulation of and instruction in a course in science demand that the teacher have a broad vision and a definite concept of the place and function of science in a liberal education. This is particularly true at the seventh-, eighth-, and ninth-grade levels, for here the objectives, content, and method have not as yet been so clearly determined as they have been in the older, more specialized courses for the later years of the high school.

In planning the science course for the early years of the high school or for the last two years of the eight-year elementary school, the administrator and the teacher who conscientiously strive to provide that science instruction which will best serve to educate the coming citizens of their community must consider carefully the following: (1) the valid objectives of science instruction at this level, (2) a plan of organization of the subject matter for effective teaching, and (3) a technique of classroom procedure which will insure the attainment of the objectives sought. The neglect of any one of these steps makes the teaching of science aimless or even harmful.

In order that administrators and teachers may understand thoroughly the plan of the *Science Problems* series, Part One of the *Guidebook* presents general considerations concerning objectives, selection of subject matter, principles of organization, and technique of instruction. Part Two contains detailed suggestions for the teaching of each unit of *Book 2*. Part Three gives lists of apparatus and materials, suggestions for ordering and caring for apparatus, and also the addresses of laboratory supply companies. Part Four presents certain bibliographical and source materials.

2. OBJECTIVES OF SCIENCE STUDY

The ultimate and practical objective or goal of science study at any level of intellectual attainment is the desirable modification of the responses of the student in life situations. What science subject matter and what methods produce the greatest beneficial result in the life of the pupil is the question which teachers must constantly ask themselves. This concept of education demands that we analyze our science materials and our methods of instruction with the hope of discovering which knowledge, attitudes, habits, appreciations, interests, and ideals are most worth-while. Many analyses of this kind have been made.

At the present time there is no conclusive method of evaluating the objectives of science study. One method which is commonly employed is that of consensus. A few years ago an analysis was made of the objectives found in fifty-one general-science courses published since 1925.* In general, the objectives may be grouped in six classes: Knowledge, Exploration, Abilities, Attitudes, Ideals and Habits, and Interests. The frequency of mention of these various objectives is shown in Table 1, pages 4-5. This frequency of mention is interesting, but is not a valid criterion for determining what the objectives should be. It reveals what others consider to be the objectives.

Another approach to the problem of deciding upon the objectives to be attained has been through appointment of committees by various associations. A committee of the National Society for the Study of Education presented its report in the *Thirty-first Yearbook* of the Society entitled "A Program for Teaching Science." This report was published in 1932. The point of view of this committee is expressed in the following quotations from the report:

> An aim of education that seems consistent with the postulations of modern philosophy is, *Life Enrichment through Participation in*

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* *Instruction in Science*, Bulletin, 1932, No. 17. Monograph No. 22, United States Department of the Interior, Office of Education.

a Democratic Social Order. . . . The point of view taken here is that life enrichment is in part, and in large part, developed from the understanding of principles and generalizations that ramify into human experience. These principles and generalizations are functional in that they furnish a background for intelligent response to stimuli that recur in common unspecialized experience. The understanding of principles and generalizations comes from the association of ideas that are developed from experiences. These understandings are products of the activities of the school if the ideas from which they are developed are products of classroom activities. It is clear, then, that the school will contribute to life enrichment if its activities are of the kind from which ideas may be developed and if the ideas may in turn be associated with principles and generalizations that are woven into human experience. . . .

A functional understanding of a principle has been attained if the learner has acquired ability to associate with the principle the ideas from his immediate and from his subsequent experiences that are directly related to it and if he is able to apply the principles in practical situations. . . . The objectives may be stated as principles and generalizations that are functional for the individual, in that they enable him to interpret the experiences of living. The objectives may be formulated (1) as statements that function directly in thinking, (2) as statements that describe methods of thinking, and (3) as statements that describe attitudes toward products of thought and toward methods of thinking. These three types of objectives, though distinguishable, cannot be regarded as mutually exclusive. From the point of view of their origins in the educative process, these objectives are closely similar. The findings from science have contributed enormously to thinking, to methods of study, and to the development of scientific attitudes that affect behavior. The principles and generalizations of science must, therefore, occupy considerable place in a program of general education the aim of which is life enrichment. (Pages 42-43)

The *Report of the Committee on the Function of Science in General Education* of the Commission on the Secondary School Curriculum of the Progressive Education Association was published in 1938. This committee states the aim of secondary education in the paragraph at the top of page 6.

TABLE 1. AN ANALYSIS OF THE OBJECTIVES LISTED IN COURSES OF STUDY IN GENERAL SCIENCE*

TYPES OF OBJECTIVES	TIMES LISTED
A) Knowledge	
1. To acquire information about science	18
2. To acquire knowledge which will produce a better understanding of our environment	40
3. To acquire the knowledge necessary to correct superstition and erroneous beliefs	4
4. To acquire a scientific vocabulary	6
5. To acquaint the student with the source of scientific knowledge.	3
6. To acquire information concerning the lives of the great men of science	4
7. To acquire a body of facts which will enable one to read scientific literature	2
8. To acquire a knowledge of the fundamental principles of the subject	2
9. To acquire a knowledge of the application of principles in industry	3
10. To acquire the knowledge necessary for future courses in science or to prepare for college	6
11. To acquire knowledge which will function to secure the objectives stated in the bulletin on Cardinal Principles of Secondary Education	
a) Health	25
b) Citizenship	19
c) Worthy home membership	13
d) Vocation	12
e) Worthy use of leisure time	14
f) Development of ethical character	11
B) Exploration (or Orientation)	
1. To give the pupil a view of the field of science so that he may explore his interests, capacities, and abilities	9
a) as a basis for the election of further courses in science	8
b) as a basis for the selection of a vocation	9
c) to acquire new fields of interest	4
C) Abilities	
1. To develop the ability to think scientifically	44
a) to develop reliance on facts	5
b) to develop the power of interpretation	10

* From *Instruction in Science*, Bulletin, 1932, No. 17. Monograph No. 22, United States Department of the Interior, Office of Education.

TYPES OF OBJECTIVES	TIMES LISTED
c) to develop the power of observation	19
d) to develop the ability to form independent judgments	12
e) to develop the ability to evaluate	3
f) to develop the ability to generalize	1
g) to develop the ability to locate problems	1
h) to develop the ability to plan prior to execution	1
i) to develop the ability to gather data systematically	2
j) to develop the ability to recognize defects and errors in conditions and processes	1
2. To develop the ability to use the scientific instruments common in the laboratory	4
D) *Attitudes*	
1. To develop a scientific attitude as shown by ability—	
a) to view facts objectively	2
b) to be free from dogma and superstition	2
c) to hold one's conclusion as tentative and to suspend judgment until facts are secured	3
d) to revise one's opinions if the evidence warrants	1
e) to have a spirit of inquiry	11
f) to be open-minded	12
g) to have a conviction of the universality of the cause and effect relationship	3
2. To develop attitudes of appreciation of—	
a) the contributions of scientific method	7
b) the contributions of science to mankind	20
c) the great men of science	8
d) expert judgment	5
e) nature	12
f) one's responsibility in the world	5
g) natural laws	4
E) *Ideals and Habits*	
1. To acquire ideals and habits of accuracy, persistence, honesty, self-control, truth, etc.	16
F) *Interests*	
1. To acquire an appetite for investigations in science	8
2. To acquire an appetite for scientific reading	9
3. To acquire an interest in taking more science	10
4. To acquire an interest in nature	10
5. To acquire interests in vocational fields	2
6. To acquire wholesome interests which may be used to enjoy spare time	14

> The purpose of general education is to meet the needs of individuals in the basic aspects of living in such way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society. Needs arise and work themselves out in living, dynamic events which can only be described as interactions between the individual and the social situation. . . . Thus when we speak of the need of the student to select and use goods wisely, we refer to a want (biological tension) or a desire on the one hand, and the requirements, demands, standards of social living on the other.*

The point of view of the committee is interesting in view of the controversy between the advocates of the "child-centered" curriculum and the believers in the "society-centered" curriculum. Advocates of the "child-centered" curriculum have demanded that learning activities be based upon the immediate felt needs or desires of pupils. Those who believe in a "society-centered" curriculum maintain that the business of education is to fit the pupil to live in an organized society. They believe that we should seek our objectives by a determination of the qualities, skills, abilities, etc., demanded for successful participation in this society. The demands of society should thus constitute the basis of our curriculum rather than the needs of pupils.

It is evident that the committee of the Progressive Education Association does not subscribe to either of the viewpoints. It rejects the "child-centered" curriculum because such a curriculum leaves out of consideration the demands of social living. It rejects the "society-centered" curriculum because such a curriculum neglects the biological tensions or wants of the individual. The committee believes that most situations have two aspects, personal and social; that the needs of the adolescent arise from an interaction between the individual and the social situation; and that the teacher must be concerned with the total situation, which includes both the individual and his environment.

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* *Science in General Education* (New York: D. Appleton-Century Co., 1938).

As a basis for the analysis and classification of needs the committee set up four centers of reference in terms of basic activities of living. These activities and the needs of adolescents to carry on these activities of living effectively are as follows:

A) PERSONAL LIVING
   1. The need for personal health
   2. The need for self-assurance
   3. The need for a satisfying world picture and a workable philosophy of life
   4. The need for a range of personal interests
   5. The need for esthetic satisfaction

B) IMMEDIATE PERSONAL-SOCIAL RELATIONSHIP
   1. The need for increasingly mature relationship in home and family life, and with adults outside the family
   2. The need for successful and increasingly mature relationship with age mates of both sexes

C) SOCIAL-CIVIC RELATIONSHIP
   1. The need for responsible participation in socially significant activities
   2. The need for social recognition

D) ECONOMIC RELATIONSHIP
   1. The need for emotional assurance of progress toward adult status
   2. The need for guidance in choosing an occupation and for vocational preparation
   3. The need for wise selection and use of goods and services
   4. The need for effective action in solving basic economic problems

The committee then considers the personal characteristics essential to democratic living. These are discussed in terms of the types of behavior that are desirable to foster. They include social sensitivity, tolerance, coöperativeness, the disposition and ability to use reflective thinking in the solution of problems, creativeness, self-direction, and esthetic appreciation.

To implement effective social participation and the realization of personal potentialities the individual must "understand the society in which he lives, the factors that are strategic in it, and the processes by which it operates and changes." The task of the curriculum-maker is therefore that of a search for the "understandings" that will bring about the desired changes in pupils. These understandings can be formulated in terms of the generalizations which when learned become incorporated in the individual as adaptations in personality resulting in intelligent behavior.

Each of these three reports has helped science teachers develop more clearly their views of the function of science in the education of boys and girls. It is in the light of these reports that the authors have selected the learning products, or objectives, aimed at in the *Science Problems* books. These objectives are as follows:

1. *An understanding of those generalizations of science that a citizen of a modern democracy needs in order to solve everyday personal, social, and civic problems.* Two criteria must be used in the selection of generalizations: (*a*) They must meet the needs of the pupils and the requirements of social living, and (*b*) they must be within the comprehension of most of the pupils who will take the course.
2. *An understanding and appreciation of the importance to oneself and to society of the applications of scientific generalizations and discoveries.*
3. *The development of a scientific attitude of mind.* One who possesses a truly scientific attitude has the following characteristics:

a) He has an inquiring turn of mind; he wants to know the what, the how, and the why of things.
b) He holds his conclusions subject to revision in the light of new evidence and revises those conclusions if the evidence warrants.

c) His judgments are as unprejudiced and as impersonal as possible.
d) He is careful and accurate in what he does.
e) He is free from dogma and superstition.
f) He is tolerant toward new ideas and suggestions.
g) He plans prior to execution.
h) He distinguishes between fact and opinion; he is slow to accept as facts, statements that are not supported by evidence.
i) He respects the judgments of experts.
j) He appreciates the value of science (both methods and subject matter) in living.

The development of a scientific attitude is a product of the method of instruction employed in the course. The teaching plan of the book, which employs the inductive method of approach to the major principles and generalizations and the problem method of organization, has as one of its major purposes the development of the scientific attitude.

4. *Growth in the ability to do critical thinking.* One learns to think by thinking. The activities, self-testing exercises, and problems to solve suggested in the course are of the type which demands reflective thinking. (An excellent analysis of reflective thinking and methods of encouraging reflective thinking is given in *Science in General Education.**)

5. *The development of wholesome intellectual interests and appreciations which lead to a desirable use of leisure time and* which give a basis for educational and vocational guidance.

The extent to which these changes take place in boys and girls through the study of science depends upon how skillfully the teacher directs the science activities toward their production. These objectives are not meaningless aims which should be read by the teacher and then forgotten. Each day's work should contribute to some extent to their realization. If this is to be the result, the teacher should know how each of the activities carried on by the pupils helps carry the pupil forward.

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* *Ibid.,* chap. vii.

3. PRINCIPLES AND PLAN OF ORGANIZATION OF THE SERIES

Before describing the method of organization employed in this series, let us consider the study materials which have been commonly used in general-science classes. Consultation with teachers of junior high-school science and observation of work done in classes reveal that much of the reading material is too difficult for large numbers of the students. This difficulty appears to be the result of a complex of several factors.

CURRENT DIFFICULTIES WITH STUDY MATERIALS IN GENERAL SCIENCE

1. *One cause of the difficulty of much general-science material is the method of organization employed.* The majority of general-science texts are organized almost entirely around environmental units or topics. When an environmental unit is presented, the generalizations of science needed to make the relationships within the unit clear are introduced when needed. In the earlier units of the course this makes necessary the introduction of an excessively large number of principles per unit, with the result that both the principles themselves and the environmental topics suffer.

To make clear the above statement, let us take a conventional unit on Weather. To develop a reasonable understanding of this unit, the following concepts and principles must be developed: temperature, radiant energy, reflection, absorption, evaporation, relative humidity, condensation, air pressure, convection currents, and the relationships of air pressure, temperature, and humidity in bringing about changes in weather. Now if we add the concepts dealing with thermometry, various forms of precipitation, areas of high pressure, areas of low pressure, isobars, isotherms, lightning, thunder, tornadoes, and weather prediction, we can easily see why such a unit is difficult. Environmental topics or units are naturally quite complex and involve a large number of relationships to interpret. Before such units are attempted, it would seem that some method must be employed to insure that a large number of the generalizations needed shall have been already developed.

Under the type of organization just discussed little if any provision is made for really teaching the principle to the point of functional understanding, that is, to the point at which the pupil can use the principle to interpret problems of a widely varying content. As a principle is introduced, application can be made only to the aspect of the environment being considered. If the principle is applied to the interpretation of any and all phases of the environment in which it supplies an explanation, the unit is thrown out of focus. For example, the idea of atmospheric pressure is introduced in the unit "Weather." It is needed to explain winds and their change in direction and in the prediction of the weather by the barometer. Now the idea of air pressure also explains how buildings are heated, pumps, vacuum-cleaners, non-skid tires, breathing, and innumerable other phenomena, devices, and processes. If we stopped, however, at this time, to use this idea to explain all of these things, weather would be entirely forgotten. The unit would be out of focus.

It is at this point that we get an explanation for the criticism of teachers that pupils do not learn the principles to the point where they will function. Really to learn a principle the pupil must practice using the principle as a method of explanation in all sorts of environmental situations. Through practice he acquires skill in analyzing situations to discover the problematic elements which determine the mode of attack and also skill in recognizing the situations in which the principle of science is the basis of explanation.

The introduction of a principle in an environmental unit results in ability to use the principle to interpret a specific situation relating to the unit at hand. Unfortunately, it does not transfer to other situations because it has not been generalized; that is, the pupil has not used the principle in a wide enough variety of situations to realize it and to accept it as a general mode of interpretation. He does not connect the air pressure which causes wind with the air pressure which operates a vacuum-cleaner or sends heated air upward from a hot-air furnace. They represent different things to him because they have not been associated in his experience.

The result of using principles only in the specific situations in which they are developed is a source of difficulty in later units. For example, a unit on water supply may follow the unit on weather. We need the idea of air pressure to explain the operation of pumps. *We assume that pupils already have the idea* because it has been presented in the weather unit. They do have the idea in connection with the specific situation encountered in that unit, but they have not really learned the principle, that is, developed it to the point of a general mode of interpretation. The teacher and the text assume that the idea is already understood; they therefore spend no time on it, and the result is that the new material becomes difficult because it assumes an understanding which is not present.

2. *Another source of difficulty is the encyclopedic treatment of concepts.* This difficulty arises in part from the fact that general-science courses cover an exceedingly large field. In order to present the vast number of concepts included in general-science courses, explanations have been condensed into as few words as possible. Psychologically this is unsound.

To make an idea easy it must be developed step by step, and this must be followed by a development of its implications. The logical outcome of such condensed encyclopedic treatment is mere verbalism. The pupil associates a principle with a series of words which have no meaning to him. It is no wonder that the principle does not become a part of his mode of behavior, that is, a method of explaining the world in which he lives. This is another difficulty that we must correct if we are to make the subject matter easier.

3. *A third source of difficulty relates to the style of writing.* This is in part the outcome of the encyclopedic method of presenting the concepts.

Other sources of difficulty are also found, but those discussed —organization of the units, encyclopedic nature of the treatment, and style of writing—are the most important.

ORGANIZATION OF THE SCIENCE PROBLEMS SERIES

Our first step in trying to eliminate these difficulties was to analyze the environmental units to discover what principles and generalizations (understandings) of science were needed to secure intelligent behavior on the part of the pupil with respect to the aspects of environment treated in the series. This analysis provided a list of all the principles needed, and, more important than this, showed the extent to which each principle was needed as a method of explanation. The analysis showed, first, the frequency of use, and, second, the importance of the principle.

For example, an understanding of the nature of chemical change was needed in the following units of the series: How do we use and control fire? How are plants and animals alike? How do plants and animals get food? Why do we eat different kinds of food? How does the earth's surface change? How do we use energy? How do our bodies work? How can you help your body fight disease? How do we take care of the plants and animals we use? How do we make electrical currents? How do we use electrical current? How do we harness the energy of nature to do our work? and How can science help us keep from wasting nature's wealth?

Apparently in chemical change we find a fundamental concept that needs to be introduced early in the course and developed to the point of general functional understanding.

In a similar fashion it was discovered that concepts and principles relating to the nature of matter, the effect of heat upon matter, the cell structure of living things, the force of gravity, and the nature and use of energy were also basic to a large number of environmental units. It is apparent, also, that these concepts have an interpretive value in their own right quite apart from their relationships with other concepts in complex environmental units.

The authors therefore decided to take these fundamental concepts and principles and organize them into real teaching units. In these units the concepts and principles are carefully developed, and the pupil is shown how to use them to interpret a wide variety of situations. Through the use of exercises and problems he is given an opportunity to practice using the generalizations to explain problematic situations. In this way it becomes possible to teach the principle to the point of functional understanding, which, as we mentioned earlier, is extremely difficult if the course is organized solely on the basis of environmental units.

The reader will see the contrast between the two methods of development if he will read Unit 2 of *Science Problems, Book 2,* "How is the force of gravity useful to us?" Fifty-two pages are used for this presentation. In the conventional general science textbook the discussion of the principles related to gravity will be found scattered through many parts of the book. In no one place will there be found an adequate development of the generalizations needed to understand this vital aspect of our everyday surroundings. Similar units are developed for the other major concepts and principles listed in the fourth paragraph on page 13. These units are placed in the course to precede the environmental units for which they supply an explanation.

With a text organized in this fashion it becomes possible to develop environmental units as they should be developed. When we consider an environmental unit, the task is to show how the various phenomena, processes, and materials which constitute the environment are interrelated to provide the conditions and effects which the environment affords. Consequently, if we are to place our emphasis upon the interrelationship, the basic principles and concepts must be regarded as prerequisite to the unit. For example, the majority of books in general science present from thirty to forty pages on weather. At least three-fourths of this space is utilized to develop the principles and concepts mentioned on page 10. A correctly focused treatment would presuppose an understanding of the principles and would focus on an understanding of how the changes in relationship between air pressure, temperature, and humidity result in changes in weather.

It is true, of course, that some science principles and concepts must be developed in each environmental unit because only those of broadest application have been singled out for special attention in units focused directly upon them. But the number of principles so needed is reduced, making the environmental unit less difficult and making it possible to focus more directly upon the understandings of the unit.

One criticism which may be urged against the method of organization is that it is a return to the old "specialized-science" type of treatment. This, however, is not the case. The specialized-science treatment is essentially deductive in character. It presents a principle and then applies it. Let us contrast this with the method employed in this book.

In general the problems in these units start with one or more environmental situations. These situations are those common in the life of the pupil and pose the question, "How can we explain this?" Then the principle is developed through experimentation. The original situation is explained, several more environmental situations are presented, and the pupil is shown how to use the idea to explain these situations. In the Self-Testing Exercises and the Problems to Solve he is given other situations to explain by means of the principle. These afford the opportunity to practice using the principle. It is really during this practice that he generalizes and makes the idea his own. Thus the teaching plan is inductive-deductive in character. It starts with an environmental situation that presents a challenge to the pupil and ends in the use of the generalization to explain new environmental situations.

Another criticism which may be made is that the presentation of science principles and generalizations in "science" units rather than in "environmental" units is opposed to the idea that science should be "socialized." This raises the question, What is meant by "socializing" science? For example, how do we socialize Archimedes' Principle? Archimedes' Principle is socialized when it can be used by the pupil to carry on more effectively the activities of everyday living, or, more specifically, when it can be used in those situations in our environment which depend upon the use of Archimedes' Principle for explanation, for prediction of possible effects or inference of conditions past or present, or for deciding upon some course of action. This means, first, that the pupil be taught to recognize the kinds of situations that may be explained by reference to the relationships presented in the principle; second, that he be able to use this set of relationships to explain causes and effects involving this set of relationships; third, that he be given practice in using Archimedes' Principle to explain those aspects of his environment which are made clear by the principle.

The crucial step in socializing a science principle is in providing for the use of the principle in carrying on the activities of everyday living. The treatment of science principles in this series is such that it does provide opportunity for the pupil to use the principle for explaining, predicting, and doing.

PLAN OF SCIENCE PROBLEMS, BOOK 1

The majority of pupils who will study *Science Problems, Book 2*, will already have studied most of the units in *Science Problems, Book 1*. For the teacher's convenience in surveying the content of the preceding book an outline is included.

UNIT 1: How Do Scientists Work?
  Problem 1: How do scientists find problems?
  Problem 2: How do scientists solve problems?
  Problem 3: How have scientific instruments helped scientists solve problems?

UNIT 2: What Kind of World Do You Live In?
  Problem 1: What conditions surround us on earth?
  Problem 2: What materials do we find in our world?
  Problem 3: What living neighbors do we have?
  Problem 4: What natural forces do we use?
  Problem 5: What kind of body do you have?

UNIT 3: What Is a Material?
  Problem 1: How are all materials alike?
  Problem 2: What are solids, liquids, and gases?
  Problem 3: What is a solution?
  Problem 4: How are materials put together?

UNIT 4: How Do Heating and Cooling Change Materials?
Problem 1: How do heating and cooling change the size of materials?
Problem 2: What effect does heating have upon the state of matter?
Problem 3: What happens to materials when they are cooled?
Problem 4: How can we explain how heat affects matter?

UNIT 5: How Can One Kind of Substance Change into Another Kind?
Problem 1: What are materials made of?
Problem 2: How can we recognize a chemical change?
Problem 3: How can we control chemical changes?
Problem 4: What are two kinds of simple chemical changes?

UNIT 6: How Do We Use and Control Fire?
Problem 1: What happens when things burn?
Problem 2: How do we make fire?
Problem 3: How do we regulate fire?
Problem 4: How do we prevent and extinguish accidental fires?

UNIT 7: How Do Magnets Work?
Problem 1: What will a magnet do?
Problem 2: How can we make magnets?
Problem 3: Why do magnetic compasses tell directions?
Problem 4: How is magnetism explained?

UNIT 8: How Are Plants and Animals Alike?
Problem 1: How are plants and animals alike in what they do?
Problem 2: What chemical substances are living things made of?
Problem 3: How are plants like animals in the way they are put together?

UNIT 9: How Do Plants and Animals Get Food?
Problem 1: How do animals get food?
Problem 2: How do green plants get food?
Problem 3: How do plants that are not green get food?
Problem 4: How do plants make food?

UNIT 10: Why Do We Eat Different Kinds of Food?
Problem 1: Why do our bodies need food?
Problem 2: What kinds of foods meet the different needs of the body?
Problem 3: How can we select our foods wisely?

UNIT 11: How Do Plants and Animals Live Together?

Problem 1: How do plants and animals depend on each other?

Problem 2: How do social animals help each other?

Problem 3: How is the balance of life maintained?

It is evident from the preceding outline that *Book 1* presents a number of concepts basic to *Books 2* and *3*. These concepts are reviewed briefly where they are first needed in Book 2, but the teacher should be prepared to give special emphasis to the review, especially when the class includes pupils who have not studied *Book 1*. In this connection a few copies of *Book 1* in the classroom or library will be very useful.

PLAN OF SCIENCE PROBLEMS, BOOK 2

The astronomy unit of the course, *What is the relation of the earth to other heavenly bodies?* was placed at the beginning of Book 2 because of its general appeal and because its development requires few general principles that are not already familiar to pupils. Furthermore, a general view of the earth as a whole and as a part of the solar system is helpful orientation for the study of such later units as those on gravity, the earth's surface, and weather. The whole treatment is intended to be scientific rather than dogmatic, yet parts of the unit serve better than others to develop the pupils' understanding of scientists' methods of thought and procedure which are introduced in *Book 1*. One such part is a sub-problem of Problem 1, "Why do we believe the earth is a sphere?" Another is Problem 5, "How do astronomers learn about the heavenly bodies?"

As we have already pointed out, Unit 2, *How is the force of gravity useful to us?* begins the development of concepts which have prime importance in later units. Here are found an introduction to the general facts about falling bodies—acceleration in its simplest aspects, air resistance to fall, universality of gravitation. Next, the discussion considers weight as an effect of gravity and the measurement of materials by comparison of gravity's pull on different masses. The term density is brought in so that it can replace the indefinite terms light and heavy in later discussions. Gravity is shown to be the cause of pressure in liquids and in the atmosphere.

Unit 3, *How does the earth's surface change?* introduces pupils to the earth as a place of constant change and shows how the changes that are going on produce many of the materials and natural features of the earth as one sees it—soil, valleys, caves, deltas, dunes, rocks, volcanoes, mountains. Much of this change is the result of gravity acting on eroding agents and on the eroded materials. Concepts developed here make the pupil more intelligent about the natural surroundings and lay an intelligent background for teaching the necessity of soil conservation which is emphasized in the unit.

Unit 4, *Why do some materials rise and others sink in fluids?* is really the development of Archimedes' Principle of flotation and its application to liquids and gases and to convection currents. The latter are not usually seen as cases of flotation. Thus the unit furthers the thinking of pupils by enabling them to see a great many separate phenomena as cases of a single principle. Essential to the study of Unit 4 are the ideas of Unit 2. Knowledge of the principle of flotation is essential to understanding convection and the circulation of the atmosphere in Units 6 and 7. However, as in the case of all similar basic units, the everyday applications are so numerous that they alone justify teaching it.

Pupils have probably used the term energy many times. They have studied about heat and light and the changes these forms of energy cause. Unit 5, "How do we use energy?" uses general experience as well as experience in science classes to broaden their conception of energy as the agent of all changes in matter. It considers the many things we do with energy, the forms in which energy is found, and emphatically introduces the changes of form which it can undergo without being destroyed. After studying this unit, repeated application for its principles will be found in everyday life and in the course.

Unit 6, *How do we control heat?* is clearly defined by its problem title. It includes the study of conduction and insulation, of radiation as a double transformation of energy, of the movement of heat by means of the convection currents of which the pupils have learned in Unit 4. However, there is much more to the control of heat and temperature than consideration of its transfer. Much heat disappears and reappears in changes of state, and so the unit includes the use of ice and of evaporation in refrigeration, of evaporation and condensation as well as heat transfer in heating our buildings.

With a good understanding of the basic principles of air-pressure, barometers, and convection currents, of evaporation and condensation, and of humidity, pupils are ready to understand reasonably well the phenomena of weather changes and their prediction by the "weather man" as they are presented in Unit 7, "What makes the weather change?" This unit is the last in this book of a dependent series which includes essentially Units 2, 4, 5, 6, and 7 and with which Units 1 and 3 have very close relations.

Unit 8, *How do our bodies work?* introduces a group of four units about living things that prove very interesting to most pupils. In this unit the pupils review without dullness the cellular structure and basic activities of living things by learning the really essential facts about the structure and functioning of the human body. A special effort has been made in writing the unit to subordinate burdensome and insignificant details to the understanding of what goes on and how it is accomplished. Essential health implications are emphasized without preaching.

Unit 9, *How can you help your body fight disease?* is a study of the kinds of germs that cause infectious diseases, how the body is equipped to ward off and destroy germs and their poisons, how we can help prevent the spread of germs and help the body overcome germs by general good health and artificially developed resistance. This study is much more effective when pupils have the understanding of the structure and functioning of the body that is developed in Unit 8.

Unit 10, *How does life continue on the earth?* is a consideration of one of the major functions of living things, that of producing new individuals. This is treated as two significant steps (*1*) the separation of pieces or cells from the parent organisms and (2) the growth and development of the separated parts into mature individuals. Plants and animals from the simplest to the highest are used as examples. Yet the intention is, as it has been in other units, to show the essential processes and principles with enough examples to give them life and reality for the pupil.

Many principles developed in the units of *Books 1* and 2 are useful in understanding the practical and scientific aspects of agriculture. Unit 11, "How do we take care of the plants and animals we use?" reviews these principles and shows how they are applied in modern farming. Included are the management of the soil moisture and fertility, combating of plant and animal pests and disease, scientific feeding, and the housing of plants and animals. If studied at the end of the year's work, the weather and farm activities make one or more excursions practical and profitable.

PLAN OF SCIENCE PROBLEMS, BOOK 3

To complete a well-rounded science course, the units of *Book 3* are needed. The outline given below will indicate the units and problems that are developed with the concepts and principles of *Books 1* and 2 as a background.

UNIT 1: How Do Living Things Behave?
  Problem 1: How do human beings behave?
  Problem 2: How do animals behave?
  Problem 3: How do plants behave?
UNIT 2: How Do Scientists Classify Living Things?
  Problem 1: What do scientists do when they classify living things?
  Problem 2: What are the kinds of animals that have no backbones?
  Problem 3: What are the characteristics of animals with backbones?
  Problem 4: What plan of classification does the scientist use?
  Problem 5: What are the different kinds of plants?
UNIT 3: How Are Plants and Animals Fitted to the Conditions Around Them?
  Problem 1: How are animals and plants fitted to live in water?
  Problem 2: How are animals and plants fitted to live on land?
  Problem 3: How do the structures of living things protect them from their enemies?
  Problem 4: How do we fit our environment?

UNIT 4: How Do Simple Machines Help Us Do Work?
Problem 1: What are machines used for?
Problem 2: Why do machines help us do work?
Problem 3: What are the kinds of simple machines?
Problem 4: How do we control friction in our machines?

UNIT 5: How Do We Make Electrical Currents?
Problem 1: How do electrical charges behave?
Problem 2: How do we control electrical current?
Problem 3: How do we use chemical change to make electrical current?
Problem 4: How do we use mechanical energy to make electrical current?

UNIT 6: How Do We Use Sound?
Problem 1: What is a sound?
Problem 2: Why do sounds differ from one another?
Problem 3: How do musical instruments produce sound?
Problem 4: How do we hear?
Problem 5: How are sound waves reproduced?
Problem 6: How do we control sound?

UNIT 7: How Do We Use Light Energy?
Problem 1: How does light behave?
Problem 2: How do we use reflected light?
Problem 3: How do we use light in our homes?
Problem 4: How do we use lenses?
Problem 5: Why are objects of different colors?

UNIT 8: How Do We Use Electrical Current?
Problem 1: How do we get heat and light from electrical current?
Problem 2: How is electricity measured?
Problem 3: How do electrical currents do work?
Problem 4: How is electrical current used to cause chemical changes?
Problem 5: How is electrical energy transmitted to our homes?
Problem 6: How is an electrical current used for sending messages?

UNIT 9: How Do We Harness the Energy of Nature to Do Our Work?

Problem 1: How is the energy of wind and water put to work?
Problem 2: How do we measure power?
Problem 3: How do we use steam to harness the energy of fuels?
Problem 4: How is the energy of fuels harnessed by internal-combustion engines?
Problem 5: How is harnessed energy transmitted?
Problem 6: What sources of energy will we use in the future?

UNIT 10: How Do We Improve Plants and Animals?

Problem 1: Why are offspring like their parents in some ways and different from them in other ways?
Problem 2: How are desirable kinds of plants produced?
Problem 3: How are desirable kinds of animals produced?

UNIT 11: How Have Living Things Developed on the Earth?

Problem 1: How do geologists discover the history of the earth?
Problem 2: What have geologists learned about the living things of the past?
Problem 3: Why do we find different kinds of living things in different places?

UNIT 12: How Can Science Help Us Keep from Wasting Nature's Wealth?

Problem 1: How can we save our soil?
Problem 2: How can we save fuel for future use?
Problem 3: How can we best enjoy our wild animals?
Problem 4: How can we make the best use of our forests?

INTERNAL ORGANIZATION OF THE UNITS

INTRODUCTORY EXERCISES. At the beginning of each unit is a series of Introductory Exercises. These exercises have four purposes: (1) They serve as a basis for recall of previous knowledge or experiences which may be of value in the study of the unit. (2) They enable the teacher to pick out the students who are poorly equipped to enter upon the study of the unit because of inadequate preparation or lack of experience with nature. (3) They enable the teacher to select the parts of the unit which

may be of general difficulty to the whole class. (4) They stimulate interest in the new unit.

LOOKING AHEAD. This part of each unit is developed in a variety of ways but always has three important purposes: (1) to help the pupil see what the unit problem really is, (2) to make the pupil feel and understand the importance of the unit to him, and (3) to arouse an active interest in the study of the unit.

PROBLEMS AND SUB-PROBLEMS. Each unit is divided into major problems focused on the larger concepts to be developed in the unit. Each problem is further divided into sub-problems focused on minor concepts essential to an understanding of the major problem. It should be noted that the problems and sub-problems are focused on understandings which have interpretive value. The subject-matter presented in the problems and sub-problems is the assimilative material or the data used by the pupil to arrive at an understanding.

SELF-TESTING EXERCISES. The Self-Testing Exercises are of two types: those testing the pupil's comprehension of the generalizations developed and those testing his ability to use the generalizations to interpret or explain problematic situations. They provide practice in using the idea.

PROBLEMS TO SOLVE. The Problems to Solve are designed to give the pupil practice in using the ideas to interpret more complex situations than those included in the Self-Testing Exercises. As such, they require a greater depth of thinking and provide opportunities for the brighter pupils. They also call for additional reading, observation, collecting, and experimenting.

LOOKING BACK. The type of summary exercise varies from unit to unit, but each has the same general purpose: that of requiring the pupil to look back over the unit, select the important ideas, and state them in concise and organized form.

ADDITIONAL EXERCISES. These exercises provide supplementary activities and problems which require further investigation for solution. They suggest projects and experiments of various kinds which may be carried out. On pages 547-554 of the text is a list of readings which may be used in this connection and also to suggest additional types of work.

4. SUGGESTIONS FOR FITTING THE COURSE TO LOCAL CONDITIONS

The authors have selected and arranged their material with great care. Where classes meet every day and the periods are not too short, each book presents an excellent year's work. When the classes meet only two or three times a week or the background and abilities of the pupils are below average, study of an entire book will probably require too superficial a treatment. In such cases it will be better to modify the course by omissions and varied treatment of units than to hurry through all of them. The teachers in each school or school system should study their own situation and choose with care the material to be taught.

Because of the interdependence of units, selections and omissions require careful examination of the sequences that have been built into the books. To assist teachers in scheduling the units and in making necessary selections of content Table 2 has been prepared. The time schedule presented in the fourth column of the table is arranged to fill 34 weeks. This is about the amount of time that will be available for teaching in a school with a nine-month term. The schedule will, of course, vary when units or parts of units are omitted. The actual amount of reading of content material and of directions for experiments is indicated in the fifth column. This quantity, together with the number of experiments to be done, is used to determine, in general, how much time will be needed for the unit in relation to the other units to be taught.

The last two columns of the table are intended to be helpful when the course must be modified for any reason. The last column indicates variations that can be made. In connection with this column it should be kept in mind that the more able pupils can often be led to study or at least read parts of a book that are not included as required work for all pupils. The second column from the right indicates what material in the book should have been studied before each unit is taken up.

Suggestions for omitting certain units should not be taken as

TABLE 2. SUGGESTED TIME SCHEDULE FOR TEACHING SCIENCE PROBLEMS, BOOK 2

UNITS	*PAGES OF READING	NUMBER OF EXPERIMENTS	TIME ALLOTMENT IN WEEKS†	COVERAGE PER WEEK		BACKGROUND MATERIAL IN PRECEDING UNITS	POSSIBLE MODIFICATIONS IN TREATMENT
				Pp.	Exp.		
1. Astronomy	39	6	4	9½	1½	Book 1: Units 1, 2	May use as a reading unit with discussion but few exercises. May change order, or omit, as seems necessary.
2. Gravity	31	8	3½	9	2†	Book 2: Unit 1	May omit Prob. 5.
3. Earth's Surface	37	7	4	9	2−	Book 2: Unit 1	May use as a reading unit, etc.
4. Flotation	18	10	2½	7	4	Book 2: Unit 2 essential (except Prob. 5)	
5. Energy	23	1	2	11½	½	Book 1: Units 2, 3, 4, 5, 6, 9, 10 Book 2: Units 1, 2 desirable	
6. Heat	30	8	3½	9	2+	Book 1: Units 3, 4, 5, 6 Book 2: Units 2, 4, 5 essential	

7. Weather	25	2	2½	10	1–	Book 2: Units 4, 6 essential Book 2: Unit 5 helpful	May be used as reading unit.
8. Our Bodies	33	7	3½	9½	2	Book 1: Units 5, 6, 8, 9, 10 Book 2: Unit 5	
9. Disease	22	1	2	11	½	Book 1: Units 9, 11 Book 2: Unit 8	
10. Reproduction Growth	32	9	3½	9	2½	Book 1: Units 8, 9, 11	Is important, but if necessary, it may be read and discussed only.
11. Scientific Agriculture	33	0	3	11	0	Book 1: Units 9, 10, 11 Book 2: Units 3, 5, 9, 10 very desirable	May be omitted or used as a reading unit.
Total	323*	59	34	Average			
				9.5	1½		

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*Exclusive of pictures, legends, and exercises. Including experiments and tables.

†Assumes school year of 34 weeks.

indicating lack of importance of the material. Necessity may require that the time spent on the course be reduced. In such circumstances it is better to omit some content or to use it for supplementary reading than to "cover the ground" at a rate which reduces interest, destroys the scientific attitude, and makes training in scientific thinking virtually impossible.

5. TECHNIQUE OF INSTRUCTION

The plan of organization of this book makes it possible to use any of the commonly accepted methods of teaching. It is a "unit-plan" book and as such is focused on the attainment of functional understandings. The assimilative materials necessary to develop these understandings are contained in the book. The teacher may employ any method he thinks desirable to use this assimilative material.

In the past fifteen years there has been a tremendous spread in the use of what is called the unit method of teaching. In this method of instruction the teaching is divided into five phases: (1) exploration, (2) preview, (3) assimilation, (4) organization, and (5) recitation. While this plan of teaching is not a necessary concomitant of the method of organization of this book, a brief statement of the technique is included here because of the many requests of teachers.

EXPLORATION

The purpose of this phase of the work has been discussed in the paragraph on "Introductory Exercises," page 23. Experience has indicated that it is a good plan to have the pupils write out the answers to the Introductory Exercises so that an individual diagnosis is possible. It is not expected that the students will be able to answer all questions correctly. Some of the exercises are based on the study material in the text. A few pupils may have progressed much farther than the average, and if their answers to the Introductory Exercises show that they thoroughly understand certain parts of the unit, they may be allowed to work on the Additional Exercises or projects.

Some teachers discuss the answers to the Introductory Exercises after they have been written. If this practice is followed, care should be taken not to discuss those exercises that are based on the new study material. The exercises which are answered in the unit and which should not be discussed will be evident from an examination of the text. After the papers have been examined by the teacher, they may be returned to the pupil at the end of the work on the unit with the incorrect exercises marked. The pupils may be instructed to correct their answers when they have completed their study of the unit. Such practice will reveal to the pupil the progress he has made and his change of viewpoint during his work on the unit.

PREVIEW

The purpose of the preview has been discussed under the section, "Looking Ahead," page 24. The preview may be presented in the form of a 15- or 20-minute talk by the teacher; that is, the teacher may read the "Looking Ahead" section as given, outline it, bring in additional illustrations of his own, and then present it in the form of an informal lecture. The introductory comments for each unit will also serve to suggest the content of the teacher's talk as an introduction to the unit. There is a wealth of historical material which may well be brought into the preview of the unit. Progress in the development of man's control of some phase of the environment supplies an excellent background upon which to project his present state of control and serves to indicate further advances which may be made. It is suggested that the teacher supplement each preview with additions of this kind. Space limitations made it impossible to present as much of the historical material in the previews as the authors think would be advisable.

If this method is followed, the pupils listen to the talk, and at the end of it are required to write out their own idea of the unit as obtained from the talk. This gives valuable training in listening and in written expression.

Another plan is to have the pupils read the "Looking Ahead"

section and then outline it. This will insure that they see the unit in its entirety and that they see the relationship of the problems and the contribution of each to the unit. Some teachers may wish to use a diagram of the unit similar to the unit graphs in this manual. Whatever method is followed, care should be taken not to include details in the preview. In his study of the unit the pupil will undertake to round out the general ideas brought out in the preview and answer the questions inspired by it.

It has been observed in some classrooms that teachers follow the presentation with a true-false test on the facts presented. This procedure does not usually follow out the idea of the presentation. It tends to become a test of what the pupil remembers of the factual statements made in the presentation. Such a method is simply a test of what the pupil remembers of what the teacher said. The primary function of the presentation is orientation. The most significant test is, "What are the problems which you will try to solve in this unit?" The answers to this question will show the teacher whether or not the pupils have caught the general idea of the unit. The answers will show whether or not the general plan of the unit is grasped; in other words, whether or not the pupils are correctly orientated.

Three general types of learning activities are employed.

a) *Listening to the spoken word.* This activity involves the ability to follow through a talk without losing the train of thought. To do this, one must be able: (1) to pick out important points, (2) to recognize that illustrations and examples are used to clarify the speaker's thought and are minor details, (3) to concentrate on what the speaker says, (4) to make a mental summary of the main points as the speaker talks, and (5) to learn to identify different methods of organization used. After the talk the pupil must be able to recapitulate the main points. This he will ordinarily do by making an outline of the main points, keeping them in sequence, and then filling in the details.

b) *Taking notes on talks.* In taking notes the same activities are involved as in listening. In addition, however, the pupil

TABLE 3. SCHEME OF INSTRUCTION TECHNIQUE

STEPS IN THE LEARNING PROCESS	STEPS IN THE CLASSROOM TECHNIQUE	STUDENT ACTIVITY INVOLVED	TESTING RESULTS
Stimulus or Motivation or Seeing the problem	Exploration (1)* or Pre-test Review previous work Recall experiences pertinent to unit	Discussion and written work	Questions and exercises
	Preview (1) Teacher's sketch of unit—15 to 20 minute talk with simple demonstrations	Listening, observing, note-taking, or Reading preview in text	Written or oral composition on preview
Study (directed) or Reflection or Solving the problem	Individual or group study (5–20)	Reading Extensive Intensive Experimentation Field trips Drawing Observation of motion pictures Observation of demonstrations Demonstration before class Responses to exercises	Oral quizzes Written quizzes Composition True-false tests Completion tests Best answer Summaries Reports on experiments Discussion before class Interpretation of new situations Self-testing exercises Problems to solve
Reaction or Application or Use of knowledge	Organization (1–2)	Preparation of outline, summary, or syllabus of unit	(The activity is itself the test.)
	Recitation (1–2)	Oral and written recitation	(The activity is the test.)

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* The numbers in parentheses following steps in classroom technique suggest the approximate number of periods to be given to each step.

must learn to write words or short phrases which will help him recall the main points of the talk. The most common error in taking notes is that the pupil will try to write everything the speaker says. This is of course impossible, and the pupil soon loses the train of thought. A good method of teaching note-taking to young students is to present part of the preview involving one main idea; then stop and show the pupils what notes they should have taken. This may be repeated until they catch the idea and are able to take notes on a talk lasting for twenty or thirty minutes.

c) *Observing motion pictures.* Sometimes the best way to get an overview of the unit is by use of a motion picture. When used for this purpose, the film should be run and followed by a discussion in which the questions or problems raised by the film are listed. These should not be answered at this time but should serve as a basis for introducing the problems of the units.

ASSIMILATION

In this phase of the work the learning activities of the pupil himself are the major concern. Through his own activity he is to gain an understanding of the problems of the unit. To guide the pupil in his study during the period of assimilation, the authors have broken up the main problems into sub-problems. These sub-problems focus the attention of the pupil on the important sub-ideas necessary to solve the problem. The great help given by the sub-problems can only be appreciated by comparing this type of organization with the conventional topical heading. The material included under each sub-problem is definitely focused on the solution of the major problem. In the majority of texts it will be found to be impossible to word the topics in the form of sub-problems and then find the material included to provide a solution for the problem.

The study material proceeds step by step, raising questions, introducing facts and principles through reading and experimentation when an actual need for them is felt. In other words, the method of teaching is inductive and is incorporated into the

study material. It is essential that each pupil solve the problem for himself, since it is through his own activity that understanding is finally reached. Fundamentally, a textbook should be regarded as a source of data for solving problems. It presents the assimilative materials which may be used to arrive at certain understandings; therefore, memory of the assimilative materials is not the end product of a course. These materials are merely a means to the end. When teaching a given unit, the teacher has in mind certain understandings, abilities, attitudes, and interests upon which the assimilative material should focus. The question is, therefore, "What activities shall I have my pupils carry on with these assimilative materials to accomplish my objectives?" The assignment (the activities set up by the teacher) is therefore the crucial factor in determining the learning products that will result.

There are many types of learning activities. Certain types are best adapted for certain kinds of learning. The teacher's task is to select that type of activity most likely to be successful in bringing about the desired result. In science a large part of the learning is essentially a process of acquiring meanings. When a thing, a situation, or an event has acquired meaning, it is understood. Perhaps the best statement of this idea has been given by Dewey: "To grasp the meaning of a thing, an event, or a situation is to see it in its relation to other things, to note how it operates or functions, what consequences follow from it, what causes it, and to what uses it can be put."

If we follow Dewey's idea, we can see that we need a variety of learning activities focused on each understanding, so that the idea may be approached from many angles. The book provides some of these angles of attack. Discussion in class can be most advantageously carried out if you formulate learning activities which attack the idea from a different angle. The more difficult the idea, the greater the number of types of learning activities that must be employed. Using a different set of learning activities for discussion from those given in the assignment also results in more thinking and greater interest.

To assist the teacher in formulating different types of learning activities, the following list is provided. When you make an assignment or prepare activities for classroom discussion, glance through this list and find appropriate types of activities. An example of each type of activity is included.

One of the objectives of an introductory science course is that of acquiring certain skills and abilities. To realize this objective, activities must be provided involving these skills and abilities, the attention of the pupil must be fixed upon correct methods of procedure, and sufficient practice must be given for the pupil to attain them. The following discussion therefore will consider some of the types of activities provided for in the *Science Problems* series and also give some suggestions for teaching pupils how to carry on these activities.

1. STUDY READING. Reading for study is of an analytical nature. The following method is suggested for this book:

a) *Read with a definite purpose in mind.* This requires a thorough comprehension of the problem to be solved. The pupil's question to himself should be "What am I trying to find out?" To test his comprehension of the problems, the student should frame it in his own words. Most pupils look upon study as learning what the text says. That is not the attitude desired in science.

b) *Read through the entire problem to get a general idea of the whole, always keeping in mind the question which you are trying to answer.* Stopping to clear up obscure points or to look up new words wastes time, because in a great many cases these will be cleared up by further reading of the problem. This first rapid reading will also furnish the pupil a basis for judging the relative importance of the different parts of the subject matter, which will assist him in distributing his time. He should look especially for sign-post or summary paragraphs and topic sentences. Pupils have become so used to studying carefully everything they read that it is sometimes difficult to get them to do this type of reading. Pupils of this age ought to read about 250 words per minute, which is about the number of words per

page. To get them to understand how you want them to read, set a time limit; that is, if the problem is five pages, give them five minutes to read it. This time varies with different classes, and the teacher can by experiment determine the best rate for each class.

c) *Reread the problem more carefully.* In this step the pupil should make a careful analysis of the subject matter. The following directions will assist pupils in this analysis:

1) Keep the problem constantly in mind and examine the subject matter in light of this problem.

2) Note carefully italicized words. These words are new words and are defined in the text. Be sure that you understand their meaning before you go on.

3) Try to picture in your "mind's eye" or make a sketch of the materials or articles described.

4) Try to relate the material to something which you already know.

5) Try to determine why the writer went from the first point to the second, and so on.

6) Use the illustrations. Each illustration or diagram was put in the text for the purpose of helping you understand more easily. Ask yourself "What does this picture show?"

7) Make in your own words a topical sentence for each paragraph. Remember that each paragraph has some one idea necessary to the understanding of the whole and that all of these ideas will furnish an outline of the problem.

2. OBSERVING MOTION PICTURES. Motion pictures provide another way of getting experiences. They should be just as carefully selected to fit into the unit or topic being studied as a demonstration or reference would be. Motion pictures are of special value as means of assimilation when it is desirable (1) to extend experiences with industrial processes or natural phenomena that are inaccessible because of time and space limitations, (2) to show phenomena and processes that are not easily observable, (3) to explain and clarify by animated diagrams, and (4) to vitalize the work.

There are certain principles of using films which have demonstrated their values:

a) The "build up" or preparation should be just as carefully carried out as for a key demonstration unless the film itself carries such a "build up."

b) The teacher should try to develop an atmosphere that will lead to the seeing of the picture as an interesting and enjoyable learning experience rather than a piece of pure entertainment or as a basis for a quiz on all of the details, which may kill the pleasure and satisfaction of seeing the film.

c) Whenever practicable, the film should be shown in the regular classroom to maintain a normal atmosphere rather than a "show" atmosphere.

d) At the first opportunity after showing the film, pupils should be given a chance to ask questions. The teacher may often start quizzing and let pupils carry on as soon as they begin asking questions.

e) After the picture has been run, use its content. Ask questions that can be illustrated or explained by what was seen in the picture.

f) After a discussion both of the picture and of the related material in the unit, it is often advisable to raise questions which are answered in the film but which were not made clear at the first showing. The film should then be re-run for this purpose.

3. LISTENING TO EXPLANATIONS. It is often advisable to supplement the study material with explanations by the teacher. Occasionally the explanation is best given before the pupils study, but as a rule the explanation should be supplementary rather than introductory. In such explanations teachers should make abundant use of the blackboard for diagrams and outlines.

If the explanation involves processes which split into different parts or phases, it is good practice to stop at the end of each phase and ask for questions upon parts that are not clear. Pupils should be made to feel that it is their responsibility to ask for further information if the explanation is not clear. If the ex-

planation is followed by a written question involving the use of the idea presented, pupils are more likely to take the responsibility seriously because they know that an explanation is followed by a quiz.

4. OBSERVING EXPERIMENTS. In observing an experiment the pupil should ask himself "What is the purpose of this experiment? What results are obtained? What conclusions can be drawn?" Younger students quite frequently look upon the manipulation of the apparatus as the end of the experiment and fail to realize that the experiment has been performed for the purpose of providing data for the answer to some question. To obtain this questioning attitude, the teacher should allow each member of the class to formulate his own conclusions. If the teacher states the conclusion, the members of the class will get into the attitude of focusing their attention on the manipulation of the apparatus, knowing that when the experiment is over, the teacher will explain it.

5. PERFORMING EXPERIMENTS IN THE LABORATORY OR FOR DEMONSTRATION. Since the method of the book is inductive in character, the experiments are introduced when data are necessary for the solution of the problem. Laboratory work is therefore not an end in itself; it is, rather, a step in problem solving. Where separate class periods are designated for laboratory work, the teacher should precede this work by a class discussion of the problems for which the experimental data are to be obtained.

If the laboratory work is to be of value, it must be carefully supervised. The pupil should:

a) know the purpose of the experiment;

b) make a careful analysis of the apparatus to be used (if necessary, an analytical drawing should be made);

c) watch everything that happens and see how it is related to the purpose of the experiment;

d) see how one step is related to another—the relation of cause to effect;

e) formulate conclusions on the basis of observed results;

f) apply his conclusions to the problem in hand.

The following directions to pupils have been found helpful in teaching them how to experiment:

a) Before you do an experiment, you should have clearly in mind the purpose of the experiment, that is, the problem you are to solve. This is necessary so that you may understand why the experiment is done in a certain way. It also helps you to get clearly in mind the nature of the facts that you are trying to discover. Ask yourself questions such as these: What is the purpose of this experiment? What am I trying to discover?

b) Next, you should read the entire experiment through to find out (*1*) how the experiment is to be performed, (*2*) the purpose of each part of the experiment, and (*3*) the kind of observations you are to make. Many students make the mistake of reading an experiment line by line, doing what the directions say. When they get through, they do not know what they have done because they have not kept clearly in mind exactly what they were trying to find out.

The best method is to read the experiment all the way through and then ask yourself: What is the first thing I am to do? What will I find out if I do this? What is the second thing I must do? etc. Another question to ask is, "Why is this method used in the experiment?" If you are going to learn to experiment for yourself, you must find out why scientists experiment the way they do.

c) Now you are ready to do the experiment. Follow directions exactly. Sometimes, of course, you may have to use slightly different apparatus from that called for, but the procedure should be followed with great care. The first lesson that you should learn about experimentation in science is accuracy.

d) Next, consider what you have learned from the experiment. In other words, what are the results that you obtained? "What did I discover from doing this experiment?" is a good question to ask.

e) Now you are ready to draw your conclusions on the basis of the facts you have collected. Your conclusions should answer the purpose in your mind when you began your experiment.

6. TAKING FIELD TRIPS. One of the most important types of learning activities in science is that of obtaining direct, first-hand contact with the materials, forces, things, processes, and phenomena of our daily environment. To a very great degree learning in science must be based upon perceptual experiencing. We may bring materials into the classroom for the pupils to observe, or we may perform experiments, but in each of these cases we are taking the thing or process, etc., out of its environmental setting. Really to understand a thing or a process we must see it in its natural setting; we must see it in its relationships to other forces, things, materials, and processes. For this reason field trips should be taken whenever and wherever possible.

There are certain principles of accepted practice that may be useful to the beginning teacher in planning field trips:

a) No field trip should be conducted without a definite purpose in the mind of both teacher and pupils. The teacher must decide ahead of time exactly what data are to be obtained on the trip.

b) The teacher must visit the places to be observed before the trip is taken so that he knows exactly what is to be seen, the location of the specific points of observation, and the order in which the observations are to be made.

c) The pupils should understand what a field trip is for and have the proper attitude toward it. They should see that things can be learned on field trips which cannot be learned from books, that on field trips they see things as they really are, and that they must know what to look for as they make their observations. They must understand that they are to keep together, that they must not talk while the teacher is talking, and that they should ask questions if they do not see what the teacher is talking about.

7. SOLVING THE SELF-TESTING EXERCISES AND THE PROBLEMS TO SOLVE. It has been found that the attention of the pupils can be most effectively focused upon the important concepts presented in the book through one or more Self-Testing Exer-

cises on each problem. Thus the Self-Testing Exercises are a very important part of the study of the problems in each unit. They serve the following important purposes:

a) Test the pupil's understanding of the problem up to that point.

b) Inform the pupil whether or not he is ready to proceed and can understand that which follows.

c) As an integral part of the study material, often refer to illustrations and to the text and thereby furnish links between what precedes and what follows.

d) Give the teacher objective evidence of the progress of each pupil.

e) Emphasize the important concepts necessary to an understanding of the unit.

f) Furnish a definite basis for self-activity.

g) Give the pupil training in measuring his own accomplishment.

h) Provide for a large number of intellectual activities of the types used in the scientific method of study.

Because of the importance of the proper use of these exercises in the correct methods of study, the teacher should see that they serve as many of the purposes listed above as possible under the teaching situation in his classes. The Self-Testing Exercises should be done by all pupils in the class. They can all be solved by proper use of the data contained in the text.

In addition to the Self-Testing Exercises, Problems to Solve have been provided. They include a wide range of activities which in general require a greater depth of thinking than the Self-Testing Exercises. As a rule, the emphasis is upon the use of the idea in explaining some environmental situation, in predicting results which follow certain conditions on the basis of science principles, or upon using the ideas to carry on some practical activity. They also include activities that are focused upon an extension of the ideas presented in the text.

The Self-Testing Exercises and Problems to Solve include the following different types of learning activities:

1. Examining a series of specific cases to arrive at a concept of class. (*What are the characteristics of a chemical change?*)

2. Examining a series of specific cases to arrive at a concept of relationship. (*How does the work put into a machine compare in amount to the output of the same machine?*)

3. Selecting facts on a given basis. (*Name three substances that are very elastic.*)

4. Judging the adequacy, relevancy, correctness of conditions, factors, statements, etc. (*In what respects does your local water supply meet the requirements of a good water supply? Criticize the following statement: Frost is frozen dew.*)

5. Comparing two processes, events, etc., to arrive at a concept of likeness and differences. (*In what ways is the human body like and unlike a machine? Compare a steam engine with a gasoline engine.*)

6. Arriving at a judgment of the relative values of two or more devices, theories, etc. (*Which kind of fuel is best for the average small home? Which theory of the origin of the solar system best explains the facts?*)

7. Experimenting. (a) To determine effect produced. (*Determine by use of an iron ball and ring the effect of heat upon a metal.*)

b) To evaluate. (*Which is the best conductor of heat—copper, or iron?*)

c) To discover relationships. (*How does the amount you can lift with a lever change when the force-arm is lengthened?*)

d) To verify principles. (*Perform an experiment to verify Archimedes' Principle.*)

e) Formulating plans for original experiments. (*Plan an experiment to find which of two vacuum bottles is the better.*)

8. Observing. (*Observe the direction and length of your shadow at different times of the day.*)

9. Discussing and summarizing, involving the selection and organizing of material. (*Discuss Law of Conservation of Energy.*)

10. Outlining. (*Make an outline of the reading material on how the balance of life is brought about.*)

11. Explaining. (*Explain why the ticket-taker on a merry-go-round leans in toward the center. Why does a region of low pressure bring rain?*)

12. Making models or devices. (*Make a waterproof sand table in which your class can see erosion occurring.*)

13. Verifying. (*Cite evidence to show that typhoid fever is caused by a germ.*)

14. Dramatizing. (*Write the directions for three people who are to demonstrate how the sun, moon, and earth move.*)

15. Reconstruction through imagination. (*Write a diary of a trip from Washington to New York in 1775.*)

16. Stating examples for the purpose of illustration. (*State an experience of your own to illustrate a chemical change.*)

17. Classifying. (*What kind of a simple machine is used in the following devices: windlass, oar, etc.?*)

18. Illustrating facts graphically. (a) Graphs. (*Make a graph to show the relationship between the season of the year and the amount of water needed.*)

b) Maps. (*Make a map to show the paths of "highs" and "lows."*)

c) Diagrams. (*Make a diagram of the ventilating system of the school.*)

d) Plans. (*Draw a plan to show how crops are rotated on a farm that has four fields of equal size.*)

e) Cartoons. (*Draw a cartoon to show the pull of gravity.*)

19. Analyzing and using graphic material. (a) Graphs. (*Given a temperature graph, when was the temperature the highest?*)

b) Maps. (*What does the map show regarding the amount of rainfall in Kansas?*)

c) Diagrams. (*Describe the apparatus shown in the figure.*)

d) Tables. (*What conclusions can you draw from the facts given in this table?*)

e) Photographs. (*How does the picture show that either the earth or the stars move?*)

20. Obtaining data from original sources. (*Find out from a manufacturer how artificial ice is made.*)

21. Taking field trips. (*Study your own neighborhood to find out what measures are taken to keep it clean.*)

Increased skill in determining types of learning activities and their uses can be obtained by classifying the Self-Testing Exercises and Problems to Solve under the types given.

8. METHODS OF USING THE EXERCISES IN SMALL AND LARGE CLASSES. The method of using the exercises will vary in accordance with the teacher's decision to use the group or the individual method of instruction or a combination of these two plans. Whatever plan is used, there arises the question of available time to mark the papers. A few suggestions for handling this important phase of the technique are therefore in order. Since the amount of time available for this purpose is largely a matter of the size of classes, the suggestions are given in two groups, one for small classes and one for large classes.

a) *Small Classes.* Before they attempt the exercises, pupils should be instructed to read through the problem for a bird's-eye view of it, and then to make a second slower reading for details. If the problem contains experiments, the pupil should perform these as he reaches them. Since pupils progress at different rates of speed, only a few sets of apparatus will be found necessary. When the exercises on a given problem are completed, the paper is handed to the teacher and is graded immediately. Thus it is not necessary for many papers to be graded after school, and, furthermore, the teacher may confer with the pupil about the paper at the psychological moment. In cases where any point is causing confusion to the class as a whole, the teacher may find it advisable to clarify the point by a brief exposition or explanation.

If the exercises are not completed satisfactorily, the papers are immediately returned to the pupil. With beginning pupils it is worth-while to indicate in the margin the type of error. In general, the faulty answers may be classified as incomplete, incorrect, too broad, or off the question. Abbreviations of these words can be used in the margin to indicate each error. The pupil then corrects his paper and returns it to the teacher as many times as is necessary for him to do the exercises correctly.

If a record is kept of the number of attempts and the types of errors made by each pupil, it can be used as a basis of conference with the pupil. Every teacher knows that exhortations on methods of study and general directions for study have little value. Pupils will change their methods of study only when they have concrete evidence that their own method will not produce results, and when the teacher can demonstrate that another method is better. The records furnish this concrete evidence and lay the foundations for selling a better method to the pupil. For this reason the procedure followed is: first, give the pupil something to do; second, show him his error, if any, and try to indicate the fault in procedure which caused the error; and third, have him repeat the exercise or give him other exercises of a similar nature.

An excellent record form for pupil progress is illustrated on page 45. This record form is mimeographed and a copy is given to each pupil. The record indicates the final date of acceptance of the activity, the number of trials or attempts required to complete the activity in a satisfactory manner, and the types of errors made. The instructor initials the last column when the activity is accepted. At the end of the unit the instructor collects these records and enters the results in a master chart as shown in Table 4 and Table 5. The time of the teacher may be saved by passing the master chart to the pupils and having them enter their results on the chart.

A typical time record of completed exercises for one of the units is shown in Table 4, page 46. Several types of pupils are shown. The table is read as follows: Pupil A completed Exercise 1 correctly on the second day, Exercise 2 on the third day, Exercise 3 on the fifth day, and so on. Pupil A also worked on the Additional Exercises on the 14th, 15th, 16th, and 17th days. Pupils A and R are consistent, average workers. Very little attention from the teacher is necessary. Pupil B either loafed at the beginning of the unit or had considerable difficulty with Exercise 1. On the evidence of the record, K looks like a loafer or a very slow learner. The fact that he worked well toward the

RECORD OF PUPIL PROGRESS ON UNIT Hour.......

Science Course.................... Name........................

Unit No......... Title...

Instructions. This sheet is to be a complete record of your work in the unit. List the written assignments of the unit in their order and attach your papers to this sheet each time you submit them, giving the date in the proper column the first time you submit a paper.

The mark on the paper at each attempt and the date of approval will be indicated by the instructor. Key to marks for errors: C—Content, M—Mathematics, F—General Form, ?—Doubtful meaning, X—English or other usage errors, I—Incomplete.

	Type of Assignment	Date	Mark on Paper					Instructor's Mark
			1	2	3	4	5	
1	*Pre-test*	*9/2*						*9/2JCM*
2	*Presentation Test*	*9/3*	*X*	*OK*				*9/4JCM*
3	*Self-Testing Exercise 1*	*9/8*	*OK*					*9/8JCM*
4	*Self-Testing Exercise 2*	*9/10*	*I*	*I*	*OK*			*9/14JCM*
5	*Etc.*							
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

TABLE 4. TIME RECORD OF COMPLETED EXERCISES

Pupils	1st day	2d day	3d day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day
A		1	2		3		4	5	6		7	8	9–10	AE*	AE	AE	AE
B							1	2	3		4	5	6–7	8	9		10
F	1	2		3		4	5	6	7	8	9	10	AE	AE	AE	AE	AE
K		1		2			3			4	5	6	7	8	9	10	
Mc	1	2	3	4	5	6	7	8–9	10								
R		1	2	3	4	5	6	Absent	Absent	7		8		9	10		

* AE. Additional Exercises.

last part of the unit when everyone else was finishing would indicate that he can work under pressure. Pupil F is a rapid, consistent worker, doing more than the average of the class (the required number of exercises was 10; Pupil F did five Additional Exercises). Pupil Mc is an extremely rapid worker. She completed the required exercises very quickly and spent the remainder of the time on a supplementary project. An examination of the number of attempts required will help interpret the results of Table 4.

The record of the number of attempts required is shown in Table 5. Each time a pupil hands in an exercise, he is credited with one attempt on it. Under the system followed it is necessary that he complete it correctly. The number of attempts therefore measures his efficiency of work. The table reads as follows: Pupil A completed Exercise 1 correctly on the first attempt. Pupil B required four attempts on Exercise 1. It will be noted that Pupil B really did have trouble on Exercise 1. The large number of attempts required classifies him as a slow learner rather than as a loafer. Pupil K is now readily identified as a loafer. His small number of attempts shows that he could not have been working during all of the time he required to

TABLE 5. Number of Attempts Required

Pupils	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Total
A	1	1	1	1	1	2	1	1	2	1	12
B	4	1	2	3	2	1	2	1	2	1	19
F	2	1	1	2	1	1	1	1	1	2	13
K	1	2	1	1	1	1	2	1	1	1	12
Mc	2	1	1	4	2	1	2	1	1	2	17
R	2	1	1	1	2	1	2	6	2	1	19

finish the unit. This conclusion, however, should be followed by observation of the pupil, because it is possible that he might be an extremely slow, conscientious worker. If he is identified as a loafer, he may be shown these charts and be asked to account for his slowness. The teacher can then show him that it is due primarily to his dilatory habits. Pupils A and F need very little attention. Pupil Mc is working too fast. She would do better to slow down and thereby decrease the number of attempts necessary. She is sacrificing accuracy for speed. Pupil R and Pupil B need more careful diagnosis and attention, as suggested by the large number of attempts necessary.

Pupils may be kept informed of how their rate of progress compares with that of others by keeping a chart record of the progress of different members of the class and posting the chart in the classroom. However, there lies in such practice the danger of encouraging hurried and careless work.

b) *Large Classes.* Where classes are so large and where the study and teaching facilities are such that individual supervision of the pupils at work is impracticable, the teacher should plan to use the exercises in such a way that they serve as well as possible the purpose for which they are intended without overburdening himself with papers to be corrected. The doing of all of the Self-Testing Exercises, or of equally valuable exercises prepared by the teacher, is quite essential to the proper study of the text. Without such activities the work is likely to fall back to the unprogressive assignment-recitation form of instruction. In accordance with the purposes of the exercises, the following flexible plans for using the exercises in large classes and under conditions unfavorable to the best teaching are suggested for the teacher's assistance in making the study of the pupil effective:

1) Have pupils write reports on all exercises. Require certain ones to be handed in for your inspection. The pupil should not know beforehand which exercises will be called for, thus insuring that he does his best on every one. Nor is it necessary to have every pupil submit the same exercises. By such plan the teacher will have a check on the work of each pupil and not

overburden himself with papers to be corrected. Exercises not called for may be taken up in class discussion, pupils being asked to read their reports for criticism by the class.

2) Pupils may be asked to hand in certain exercises and to make brief notes on the points which they would include in reports on those not collected. The latter may then be considered in class discussion.

3) Pupils may be asked to write an answer to each of the sub-problems raised and to the major problems. The teacher can then first read the answer to the major problem. If this is correct, it is not necessary to read the answers to the sub-problems. If the answer is incorrect, the error will usually be found among the answers to the sub-problems. In case such an error is found, the teacher may direct the pupil to solve the sub-problem again and then to solve the major problem again.

4) Where the technique is entirely of the group instruction plan, pupils may be asked to make notes for their reports on each exercise in the text or to write their reports and be ready to report in class discussion of the problem. This is probably the least desirable of the plans suggested, for it does not, per se, insure individual thinking and activity, and does not lend itself so well to directed or supervised work.

5) If the group method of instruction is carried on, it is essential that it be adapted to the spirit of the book, which is inductive. First, a problem is raised; this is in turn broken up into smaller problems, each of which is solved by the presentation of certain data or by experiment, and the results of all are combined into an answer to the problem. As a rule this final combination organization must be done by the pupil in answer to the exercise.

A good method of group instruction is therefore to raise the problem with the pupils and get it firmly in mind by requiring several restatements of it by the pupils. Then have the class read through to the first experiment. This experiment may then be performed by the teacher in demonstration, or it may be performed by the pupils working in groups, or by the individual pupils, or by some one pupil. It is important in this connection

to let the pupils draw their own conclusions. Then turn back to the reading of the problem until another experiment is reached, and go through the same process.

When all of the experiments have been performed and the class has finished reading through the problem for the first time, set them doing the exercises. This in most cases will require further study of the problem. In order to be sure that each pupil does his own work, it is essential that these exercises be done in class if possible. Some of the brighter or faster pupils will probably finish before the rest of the class, and these may be supplied with additional exercises or supplementary projects until the group is ready to go on. Before beginning the next problem, it may be advisable to have a class discussion of the previous problem to insure that all have obtained an understanding. Any pupil who has done his exercises incorrectly can then correct them.

A plan such as outlined breaks the period into several parts: study, experimentation, and discussion.

ORGANIZATION

When the students have given satisfactory evidence (in assimilation tests) that they thoroughly understand a unit, that they really know the essential facts and relationships, they should proceed to the next step in the learning process—organization. Without books, notes, or other helps, each pupil is required to represent in some way the relative importance of the ideas in the unit and their interrelationships. The organization may take the form of (*a*) a list of the main ideas in statement form, (*b*) a statement or topical outline of the unit, (*c*) a diagram of the unit (see the graph for each unit).

There is a marked tendency for the pupil to include a large amount of assimilative material in the organization. This is particularly true if the outline is made too detailed. At first, it is probably best to have pupils make only the main points. As they attain skill in this process, they may be allowed to make their outline in more detail.

The organization, if properly used, provides a strong stimulus for thought about the facts and relations of the unit. It is not

to be regarded as a test, but as a step in the learning process. However, in so far as it is a thinking exercise and not an outline of the memorized text discussion, it is a quite reliable index of the pupil's ability to organize facts in a conscious and independent way. More than any other assignment of a unit, it stimulates growth in thinking power. (For detailed suggestions see the "Looking Back" sections and the unit graphs in this manual.) Motion pictures are often very helpful in showing pupils the unit in perspective and assisting them in picking out essential elements.

RECITATION

Following the completion of the organization by all the pupils, one or two periods may be given to oral or written recitation. The selection of recitation topics and the procedure in the recitation may follow several different plans, depending somewhat on the type of unit. In many cases the topics should be such that they will call for a re-presentation of the entire unit under a new organization. In other units a presentation of some part of the unit is advisable. Under any plan used, the student is expected to present his talk in a clear, well-organized, straightforward fashion, and in good English. He should assume that he is speaking to an audience made up of those who have not studied the unit. Any member of the class or the instructor may call upon the student to elucidate any point in his talk. Following the oral recitations those pupils who have not given satisfactory recitations and those who have not had an opportunity to speak may be required to write on a topic selected by the instructor.

In order to add interest to the recitation, the instructor may suggest to the pupils that they incorporate in their talk any additional material obtained from their reading or from talking the topic over with their parents. Pupils interested in some one phase of the unit may have done additional work on this phase. They can also be given opportunity to present the results of their investigation. The instructor may also suggest topics not directly based on the problems of the unit but re-

quiring that both speakers and listeners use their new understandings.

It is commonly the practice where the group plan of instruction is used to have a series of recitations on small blocks of the subject matter from day to day. It is highly advisable, however, to carry on the recitation for the whole unit as outlined above. This will furnish a review and will also insure that the unit is seen in its entirety rather than as a series of apparently unrelated facts and principles.

CORRELATION WITH OTHER SUBJECTS

The written work in science affords the opportunity for correlation with the English department. The preview and the written recitation, both in narrative form, give excellent training in English composition. After the paper has been corrected for science, it may be turned over to the English teacher for further correction or elaboration. The organization, which is usually written in outline form as a series of statements, will also give the English teacher concrete material upon which to work. This may also be sent to the English teacher for correction. Quite often the English department will arrange to give credit for the written work in science. Drawings of apparatus, machines, etc., can often be arranged for in connection with the manual-arts department. Concepts developed in Units 1, 6, 9, and 11 have important social implications and give opportunity for making direct connection with topics usually included in social-studies courses.

TESTING RESULTS

Several methods of testing results have already been referred to, namely, the exercises, organization, and written recitation. If the individual plan of instruction is followed and the pupils are required to work on the exercises until they are correct, the number of attempts required is a good measure of efficiency. The number of days required to complete the exercises correctly is a good measure of their rate of work. For use in grading it is possible to give a passing grade for the correct completion of a given number of exercises and to base higher grades on the completion of a given number of additional ex-

ercises or supplementary projects. This will set up a definite standard of accomplishment for the class. The organization furnishes evidence on the extent to which the pupil has visualized the whole unit and upon his ability to grasp the interrelationships of the problems which make up the unit.

In addition to the above measures many teachers find it advisable to give a test on the entire unit. Such objective types as the true-false, the completion, and the best-answer can be used to good advantage in this connection. These tests have the advantage of being easily scored.

6. PRINCIPAL TYPES OF DIFFICULTIES ENCOUNTERED BY PUPILS

Real teaching does not stop with marking the exercises as correct or incorrect; it goes further and tries to diagnose the cause for the difficulty and to give corrective treatment. A list of difficulties, with diagnosis and corrective procedure, follows.

1. Misunderstanding the text or exercise. This is due in some cases to carelessness in reading the text or exercise and in others to attempting the exercise before having a complete understanding of the text. The most common types of errors are incomplete answers, incorrect answers, and off-the-question answers. These can frequently be corrected by having the pupil write the title of the exercise in his own words and show it to the instructor before he begins. Pupils who habitually misunderstand the exercises should be shown the value of the habit of restating the exercise in their own words.

2. Failure to identify the type of work needed to secure the answer. When confronted with a thought question, many pupils simply read the question over and then hunt through the text to find the answer. If they cannot find some direct connection between the thought of the question and some passage in the text, they give up and inform the teacher that the answer isn't there; others find a few phrases in the text which are similar to those used in the test and write them as an answer; others write everything they can find that has any bearing on the question. This results mainly in answers which are off the ques-

tion or too broad, with a sprinkling of incorrect and incomplete answers. Here again the pupils must be shown that their faulty answers are due to incorrect methods of procedure.

Corrective work, of course, varies with the type of test. In some cases the pupil has failed to strip the question of its setting, and thus cannot identify it with the correct principle or application. Corrective work consists in having the pupil (1) restate the exercise in his own words, (2) ask himself, "What do I have to know to answer this exercise?" and (3) ask himself, "How shall I go about getting the answer?" When a pupil has difficulties in determining his method of procedure, the teacher should show him the method to be used in that case, and then give him practice in problems of a similar nature.

3. FAILURE TO SEE RELATIONSHIPS BETWEEN EXPERIMENTS AND SUBJECT MATTER. *Science Problems* is inductive in character and proceeds from applications to principles. For example, the pump is first studied as a working device, and then experiments follow which present the principle of science involved in its operation. Many pupils become so interested in the manipulation of the apparatus that they lose sight of the purpose of the experiment. The experiment thus tends to become something apart from the problem. Since the text is inductive, each experiment contributes some one fact or principle necessary for complete understanding. Consequently a pupil who has not grasped the relationship between the experiment and the subject matter either gives up or frames some totally inadequate answer.

Since not all of the problems are experimental, it is very easy to identify such a pupil. In correcting this error the teacher must prove to the pupil that his faulty answer was due to a failure to see the contribution of the experiment. If on the next problem which includes experiments he is required to write out the principles or facts presented by the experiments and then to do the test, the ease with which he can do the test gives him concrete evidence of the value of the method. Some teachers will prefer to have pupils write a report on each experiment.

4. TENDENCY TO MEMORIZE THE TEXT RATHER THAN TO RATIONALIZE IT. Pupils who memorize rather than rationalize

can be identified by observation. They read the text over and over, frequently turning their eyes away from the book and gazing off into space. Many of them move their lips as they say over and over the words of the text. The results of memorizing the text are also apparent in the test results, which frequently contain a word-for-word reproduction. This practice is soon broken up if the tests are so constructed that they call for reflective thinking with the memory element in the background.

5. TENDENCY TO FORM CONCLUSIONS WITHOUT WEIGHING THE EVIDENCE. The tendency to form hasty conclusions appears quite frequently and results in incorrect answers. Such pupils generally have a large number of attempts on exercises. If the record of attempts is kept by days, these pupils can be readily identified by the large number of attempts on any given day. This type of pupil is usually very fertile in suggestions, but he does not evaluate these suggestions sufficiently before formulating his response.

The habit which must be broken is that of taking the first suggestion which comes to mind. The habit to be inculcated is that of recalling or formulating as many solutions as possible, and then testing each solution in the light of its applicability to the problem at hand. The tendency also results in incomplete answers. In a question which involves putting together several ideas contained in different paragraphs, some pupils obtain a partial answer in one paragraph and then fail to combine with it equally important ideas in other paragraphs. This may be caused by the fact that the pupil has not studied the problem as a whole and has failed to grasp the organization.

6. INABILITY TO DISTINGUISH BETWEEN MAJOR AND MINOR POINTS. The inability to select essentials crops out most frequently in making outlines and summaries. In many cases it is caused by lack of knowledge concerning chapter and paragraph structure, in others to a lack of definite purpose on the part of the pupil in his selection of facts. Here the pupil should be taught the significance of the problem and sub-problem titles in guiding him in the selection of his facts and the use of signpost and summary paragraphs and topic sentences.

7. FAILURE TO USE OR INTERPRET DIAGRAMS, TABLES, ILLUSTRATIONS, AND CROSS-SECTION DRAWINGS. Many pupils regard illustrations as something to be looked at and then passed over. As a result of this habit many pupils do not know how to study illustrations or read diagrams, tables, graphs, and section drawings. This is particularly true of section drawings. In order to assist pupils in the interpretation of such drawings it is sometimes necessary to have both an illustration and a section drawing of the same device. Practice can also be given in making section drawings from the actual apparatus.

8. INABILITY TO TRANSLATE THE PRINTED WORD INTO A THOUGHT-PICTURE. An example of inability to translate words into thought-pictures is found in describing the operation of a pump. Many pupils memorize the steps in the operation without actually seeing the significance of each step. One way to identify such pupils is to have them draw the pump in different stages of its operation. For example, suppose that the section drawing in the text shows the piston and the position of the valves at the beginning of the first upstroke, and the rest of the operation is explained in the text. If the pupil is asked to show the position of the valves and the piston on the first downstroke and the second upstroke, giving reasons for the different positions of the valves and the rise of the water through the cylinder, he will be forced to rationalize the process. Many pupils can tell glibly how the pump operates without having the slightest understanding of its operation.

9. SUMMARY. The results obtained in following the procedure outlined are evidenced in three ways: the reduction of the number of attempts required to do the test exercises, the reduction in the number of errors, and the reduction in time required to complete the units,

The supervision of study in beginning courses of science consists in setting up definite tests, the results of which are used not only to determine the extent of the pupil's understanding but also to find out the incorrect methods of procedure which are responsible for faulty answers. The results also furnish the basis for teaching pupils how to study.

PART TWO

Specific Suggestions for Class Work on the Units

INTRODUCTION TO THE COURSE

It is suggested that at the first class meeting teachers call the pupils' attention to the frontispiece of the book. This figure is an actual reproduction of headlines and parts of articles that appeared in newspapers and magazines during a short period of time. Get the pupils to state from the figure, words whose meanings they do not know and topics they think are most interesting. The teacher may list these on the board as they are given. Then have the class read the section entitled, "Finding the Meanings of Things," pages v-viii. Pupils who have used *Science Problems, Book 1,* may run quickly through pages vii-viii and go on to survey the table of contents, pages ix-xi. The content of the book should then be tied up with the frontispiece by having as many as possible of the headlines in the frontispiece connected with a definite unit in which the pupils expect to learn more about that topic. Some headlines may be connected with what the pupils have already studied in *Book 1.* This introductory activity should serve the following purposes for the pupils:

a) Introduce them in an interesting way to the content of the book and help them see what is included in the book.

b) Review the method of organizing the units and problems.

c) Review the uses of the various learning devices included in the textbook.

It is urged that the teacher make sure that all members of the class understand the method that is to be used in the study of the book and the purpose of each learning device that is to be utilized. Of course much of this will become clear only through daily work in the class, but a careful introduction saves much useless floundering, especially for pupils who are new to the school and to the *Science Problems* series.

Teachers should previously have read Section 5, Part I, pages 28-53 of this *Guidebook* to be thoroughly familiar with the function of the learning activities and with the unit organization.

In addition to serving as an orientation for the course, study of the frontispiece may well be the stimulus to set the members of the class searching for current articles for later class discussion and for a science bulletin board. In many classes the weekly current science period may well grow out of this beginning. Refer to page 282 for a list of science publications that may be useful in addition to general newspapers and magazines.

UNIT 1

What Is the Relation of the Earth to Other Heavenly Bodies?

FUNCTION AND SCOPE OF UNIT 1. This unit is placed first in this book because (1) it provides a vantage-point for viewing the earth and the living things upon it in their proper relation to the universe, (2) it is of tremendous interest to pupils, and (3) it provides material for the interpretation of other units of this series. Units 3, 7, and 10 of this book and Unit 11 of *Science Problems, Book 3* are particularly meaningful when they are studied with the ideas of this unit as a basis.

The graph of Unit 1 on page 59 will assist the teacher in seeing the unit as a whole and in selecting the points to be emphasized in the study of the unit. Accurate, detailed facts are necessary in all science work, but they only serve their purpose when they lead pupils to a clear understanding of the main ideas. When, through use of the facts the pupils have gained understanding and appreciation, the objectives of the teaching have been attained. Careful study of the unit graph by the teacher will pay high dividends in clarifying the objectives of the unit.

The material of this unit is arranged to begin with something

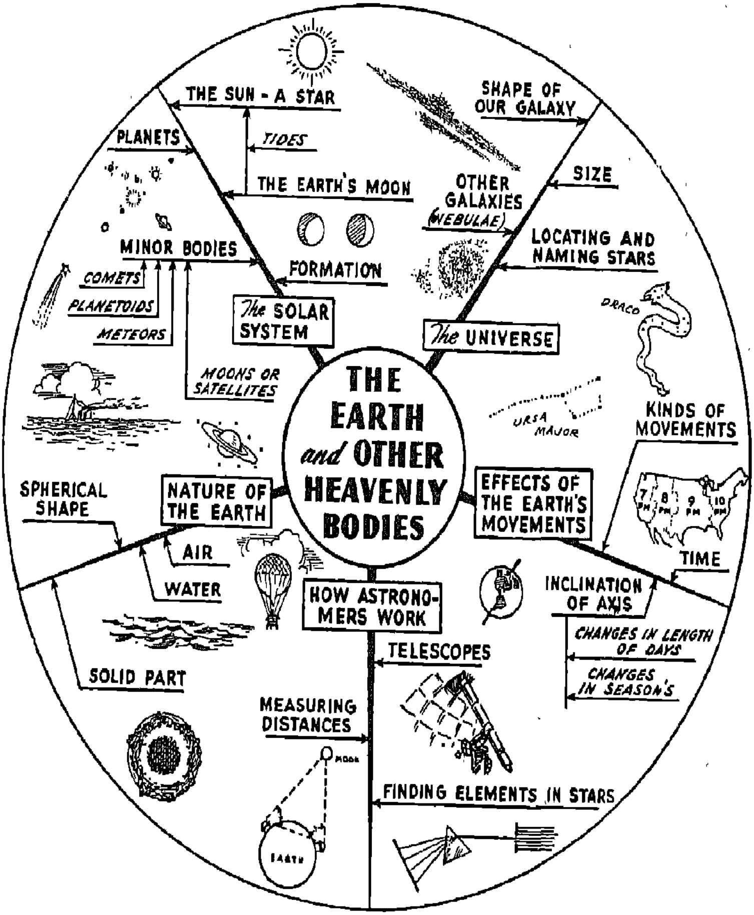

FIG. 1. GRAPH OF THE SUBJECT MATTER OF UNIT 1

with which the pupils are more or less familiar—a brief consideration of the physical make-up of the earth. Following this, a study of the interrelation of the heavenly bodies (the solar system and its origin, and our galactic system) provides knowledge for interpreting the materials, forces, and phenomena which affect the everyday life of man and for building a significant part of the pupils' own "world picture."

During the study of the different parts of the unit, pupils are certain to ask how man has gained his knowledge of heavenly bodies. Consideration of the accuracy of scientific methods of experimentation and the amazing results which are obtained by their use are developed in a brief study of telescopes and spectroscopes. These two of the astronomers' most important tools plus careful methods of investigation should be presented as having led man from a state of dependence upon superstition and conjecture to the place where accurate information concerning heavenly bodies is available.

INTRODUCTORY EXERCISES (P. 2). 1, 2, 3. Responses will vary. If carefully done, any reasonable response should be accepted.

4. Rotation on axis and revolution around sun. Pupils will give various ways to detect these movements. If there is opportunity for discussion it should be brought out that the best observers thought for thousands of years that the earth stood still and the heavenly bodies circled about it. And the question may still remain open: "How do we know?"

5. If you look out over a great flat region like the ocean or a prairie to the horizon and watch a ship or something approach, you do not see it all at once, but the top is visible first. During eclipse of moon, when earth's shadow is on moon, it can be seen that earth is round. If you are high enough above earth's surface, you can see the curve of the earth.

6. From west to east. Sun is seen first in east each day. This shows that east approaches sun before west and that earth turns from west to east.

7. An hour slow because Washington is east of St. Louis. Sun is seen at Washington first, with result that it is one hour later in Washington than in St. Louis.

LOOKING AHEAD TO UNIT 1 (P. 3). Techniques for presenting the introductory material of the units of *Science Problems, Book 2* are given on pages 29-32 of this *Guidebook*. The teacher should refer to these pages and select the method which seems most profitable for the material of this unit and for his particular group of students. This introductory material should not be treated in detail, since one of its main functions is to stimulate interest and questioning. During the study of these pages, the following objectives should be achieved: (1) Leading questions from the text material or from the pupils' experiences should arouse curiosity and stimulate interest. Examples of such questions are, "Why does the moon appear to change its shape?" "How do scientists know the earth is turning? How can they tell how far it is to the moon?" (2) The brief historical material used should show that astronomy is a very old science. (3) The application of the scientific method of problem solving has changed the beliefs of thinking people from the superstitions of astrology to the principles of astronomy. (4) The development of man's ideas has paralleled the development of accurate scientific instruments (e.g., the telescope).

PROBLEM 1: WHAT IS THE EARTH? (P. 6)

The use of a large relief map, or better still, of a globe such as the one shown in Figure 4, page 7, should be used in reviewing familiar facts about the earth's shape and dimensions.

Use the method on page 9, that is, requiring the pupils to present the idea that the earth is a sphere as if they were trying to convince someone of this fact. Different pupils or groups of pupils may present each of the reasons given. Experiment 1 should be a pupil demonstration. In connection with lunar eclipses as one of the proofs it will probably be necessary to explain briefly, by diagram or demonstration, what an eclipse of the moon is. Detailed information on eclipses can be more profitably developed in connection with the material on pages 29 and 30.

The term *hypothesis* should be reviewed until it is thoroughly understood. Then the *Planetesimal Hypothesis* should be presented as the best explanation scientists have today of the origin of the solar system. The main ideas of the problem are:

1. The solar system consists of the sun and the other bodies which move round it.
2. The sun is a mass of extremely hot gases many thousands of times larger than the earth.
3. The sun provides light and heat for the solar system.
4. The surface of the sun has violent storms which appear from the earth as sun spots.
5. Planets are smaller bodies which move about the sun at different distances.

a) The paths of planets about the sun are known as orbits.
b) Planets are made of materials somewhat like those of the earth.
c) Planets shine by means of reflected light.
d) Planets differ in the lengths of their days and years.

6. Planetoids are tiny planet-like bodies which travel around the sun in orbits of their own.
7. Comets travel in elliptical orbits about the sun.
8. Meteors are small bits of material that fall into the earth's atmosphere. When meteors reach the earth, they are known as *meteorites*.
9. Moons (or satellites) revolve around planets.
10. The earth's moon has no living things upon it because it is known to have no atmosphere.
11. The markings upon the face of the moon are really mountain chains, craters, and vast plains.
12. The moon is visible because it reflects sunlight.
13. The shape of the moon appears to change gradually because we see differing amounts of its lighted half as the moon moves around the earth.
14. Eclipses occur when

a) the earth is between the moon and the sun (lunar).
b) the moon is between the earth and the sun (solar).

15. The gravitational pull of the moon and sun upon the earth causes tides.

16. The solar system is believed to have originated from the sun when another star came close to it.

Self-Testing Exercises (p. 23). 1. Answers vary but should indicate a correct "mental picture" of the solar system.

2. Because of kind of light that comes from sun. Light from stars and light from sun are of the same kind.

3. Gaseous, because temperature is much too high for material to be in liquid or solid state.

4. A heavenly body that shines mainly by reflected light of the sun and that revolves in an orbit around sun.

6. Pluto.

7. Very little, if any. They are probably made of material somewhat like that of the earth and shine by reflection of sunlight.

8. Mercury differs from earth as follows:

a) Much nearer the sun.

b) Turns very slowly on its axis and makes only one rotation while it is revolving around the sun.

c) One side is very hot and the other very cold, because the planet keeps same side facing sun at all times.

9. Mercury, hottest; Pluto, coldest. Mercury is nearest sun, and Pluto farthest from sun.

10. Planetoids are much smaller than planets.

11. Comets are masses of gaseous material that travel around the sun in elliptical orbits. Long tails of gas streaming from them; these tails always point away from sun.

12. A meteor is a small body of material that falls from space into earth's atmosphere. Gives out light because friction with earth's atmosphere makes it become very hot.

Problems to Solve (p. 23). 1. Pluto has longest "year," since it takes 247.7 of our years to revolve around the sun. Venus has longest known day since it requires 224.7 of our days to rotate.

2. Pluto, Neptune, Uranus.

3. (a) Ways in which planets are alike:

1) Each revolves around sun in an orbit of its own.

2) Each rotates on an axis.

3) None gives out much light of its own; all reflect light from sun.

b) Some ways in which the planets differ: (*1*) In size. (*2*) In temperature. (*3*) In time of revolution around sun. (*4*) In time of rotation on axis. (*5*) In distance from sun. (*6*) In appearance to naked eye—color, etc. (*7*) In number of moons.

4. 53 + years (200 m.p.h. times 24 = 4800 m. per day. 365¼ × 4800 = 1,753,200 miles a year. 93,000,000 ÷ 1,753,200 = 53 + yr.)

5. Mercury = ¼ in. Mars = ⅜ in. Uranus = 2½ in.
Venus = ⅝ in. Jupiter = 7¼ in. Neptune = 2⅞ in.
Earth = 7/10 in. Saturn = 6 in. Pluto = 4/5 in.

6. 8 1/3 minutes.

7. (a) Planets do not shine with their own light, but with reflected light.

b) Planets consist of solids, and some have liquids and gases. Stars are entirely gaseous.

c) Planets revolve around the sun; stars do not.

d) Planets get heat only from sun which is a star; stars give out heat themselves.

EXPERIMENT 2. WHY DOES THE MOON APPEAR TO HAVE DIFFERENT SHAPES AT DIFFERENT TIMES? (P. 27.) Apparatus and materials needed for the experiment are: Strong light source on a stand about four feet high; tennis ball; ping-pong ball.

This experiment should be done individually by each pupil. The directions for performing the experiment are self-explanatory. Have pupils draw shapes of the lighted part of the ball at the different numbered positions in Figure 21, page 28. Have them compare these sketches with actual appearance of the moon in its different phases.

A variation of the experiment which often gets excellent results is to have a group of pupils copy Figure 21 on a sheet of dark cardboard about three feet square. Use a slide projector, strong light bulb, or flashlight placed several feet away to represent the light from the sun shining upon the moon and the earth. Use a tennis ball for the earth and a ping-pong ball for the moon. The tennis ball may be secured to the cardboard by driving a nail into it from underneath the cardboard. Move the ping-pong ball into the various positions shown in Figure

21. Note: *Always have the pupils stand in such positions that they can see the ping-pong ball by sighting over the top of the tennis ball.* Use as an individual experiment for each pupil and have results recorded.

SELF-TESTING EXERCISES (P. 31). 1. Sunshine is light of sun itself. Moonshine is sunshine reflected from surface of moon.

2. Because moon has no air, no soil, and no water.

3. Paragraph should include these ideas: Moon and earth are spheres; only half of moon lighted by sun at any one time; moon revolves around earth; one sees different amounts of lighted half of moon when moon is in different positions as it revolves around earth.

4. Can see the shadow of the earth falling on the moon. This happens because the sun, moon, and earth are in a direct line with the earth between the sun and moon.

5. Shadow of moon on earth's surface. This happens because the sun, moon and earth are in a direct line, with the moon between the sun and earth.

6. Two high tides.

7. By gravitational pull of moon on water of earth.

PROBLEMS TO SOLVE (P. 32). 2. At full moon.

3. Just at the time called new moon by astronomers (when the moon passes the line between the earth and the sun).

4. At new moon and at full moon. At these times sun and moon are in line with each other, and their attractions act together to produce the very highest tides.

5. Yes. Light from moon is sunlight reflected from surface of moon and not light given off by moon itself.

6. No. Moon is rotating on its axis as it and earth travel around sun. Although speed of rotation is such that moon always keeps same side toward earth, during time of revolution around earth all faces of moon have turned toward sun.

7. If earth is a ball 2 inches in diameter, ball representing moon should be ½ inch in diameter. Allowing 1 inch to equal 4000 miles, moon should be 60 inches or 5 feet from earth.

8. Because orbit of moon is inclined to plane of earth's orbit, or ecliptic, and does not move exactly in the same plane, sometimes the moon passes "above" the line through the earth and sun and sometimes "below" it.

9. If earth is ball 2 inches in diameter, ball representing sun should be 218 inches (864,392 ÷ 7918 × 2), or 18 1/6 feet, across. Should be 23,250 in. (93,000,000 ÷ 4000), or 1937.5 ft., from earth.

SELF-TESTING EXERCISES (P. 36). 1. Explanation in student's own words of Planetesimal Hypothesis. Should include these ideas: Millions of years ago star passing near sun pulled on sun and pulled out some gaseous material; swirling motion of gases around sun kept material from falling back into sun; pull of sun kept material from flying off into space; gaseous material cooled and changed into many small solid bodies called planetesimals; bodies small at first but built up by adding material to them as they journeyed around sun; formed present members of solar system.

2. As newly formed earth traveled around sun, it passed near some of the small planets or planetesimals. These were attracted to the earth by the force of gravity and became part of the earth.

3. A fact is a happening that has been observed or proved to have happened. An hypothesis is an explanation that seems to explain the facts but cannot be actually proved to be correct.

PROBLEM 3: WHAT IS THE NATURE OF THE UNIVERSE? (P. 36)

From the study of the preceding two problems the pupils will have gained the ideas that the earth is large but that in comparison with the size of the earth the entire solar system is indeed vast. The study of this problem should further enlarge their concept of the vastness of space when the galactic system is studied along with the innumerable bodies in all of space. Also, the realization that the earth, important though it is to human beings who live upon it, is very insignificant in comparison with other heavenly bodies, should be very clearly understood by the pupils from the study of this problem. However, it is better to let the realization grow on them as they group the facts than to present the ideas as a statement and have the pupils repeat it.

A brief study of constellations is included because of its great interest and because it gives an opportunity for field work.

The main ideas to be developed in the problem are:

1. Stars and the sun are the same kind of bodies.
2. The sun and the planets are insignificant when compared with other bodies in space.
3. The universe includes all of the bodies in space.
4. The term light year is used to measure great distances in space.
5. Astronomers believe that the sun and its family belong to a great group of stars known as a galactic system, or galaxy.
6. There are many galaxies in all of space.
7. The size of the universe is too great for us to imagine.
8. Many different constellations can be seen during different seasons.

SELF-TESTING EXERCISES (P. 44). 1. The universe is everything that exists in space.

2. A number of stars that appear to form a group in the sky.
3. Distance light travels in one year. Used as a measure of distance because distances are so great that use of the mile would result in enormous figures.
4. North Star is almost directly above north pole of earth.
5. (*a*) Galaxies, (*b*) Stars, (*c*) Planets, moons, planetoids, comets, stars.
6. Because as the earth revolves around the sun the dark part of the earth is turned toward different parts of the sky.
7. Because it is made up of innumerable stars all giving off light. We are looking out toward a great many stars so that the whole area looks light.
8. Flat and disk-like in shape; thicker at center than at edges.
9. 133,920,000 years.

PROBLEM 4: HOW DO THE EARTH'S MOVEMENTS AFFECT US? (P. 45)

During the study of the preceding problems of this unit, the pupils will have gained ideas of the relationships of the earth to other heavenly bodies. This problem focuses attention upon the effects of the movements of the earth upon conditions on the earth. Since this problem provides material directly applicable to conditions upon the earth which affect living things, it should be carefully developed. The main ideas to be developed are:

1. Because the earth is rotating upon its axis, places having different longitudes have different time by the sun.

2. The United States has been divided into Standard Time Zones to avoid confusion.

3. The axis of the earth is inclined to the plane of its orbit at an angle of 23½ degrees.

4. Because of the inclination of the earth's axis (*a*) the northern half of the earth is more than half lighted in summer; thus, days are longer in summer.
b) the northern half of the earth is less than half lighted in winter; thus, days are shorter in winter.

5. The rays of the sun strike the earth at different angles in different seasons.

6. The earth (northern hemisphere) receives more light and heat in summer than at the same hour in winter because the rays of light are more nearly vertical in summer and, thus, are concentrated upon a smaller area.

7. The sun's rays pass through less air in summer and, as a result, lose less of their heat before striking the earth's surface.

EXPERIMENT 3. WHY DOES THE LENGTH OF DAYS AND NIGHTS CHANGE? (P. 46). Materials needed for the experiment are:

Knitting needle about 6 inches long or stiff piece of wire
Tennis ball
Block for base to support ball
Piece of paper about 30 in. sq.
Candle.

This experiment may be done at home by individual pupils and then repeated in class (if the classroom can be darkened sufficiently) to be sure the pupils understand it. Caution the pupils to keep the center of the candle flame on a level with the center of the ball and to keep the axis of the ball pointing in the same direction in each of the four positions.

a) Ball lights up from pole to pole in each of the four positions. Lengths of days and nights would not change with the seasons if axis of earth were perpendicular to plane of its orbit.

b) Half of ball is always lighted, but ball is not lighted from pole to pole at all seasonal positions. Lengths of days and nights are equal when ball is in autumn position.

c) Days are shorter than nights when ball is in winter position.

d) Days and nights are of equal length in spring position.

e) Days are longer than nights in summer position.

Self-Testing Exercises (p. 48). 1. Because earth is in position in which it is lighted from pole to pole; thus dark side and light side of earth are of equal extent.

2. Because in winter the sun lights less than one half of our "end" of the earth, while in summer more than half of it is lighted.

3. (*a*) That axis of earth is tilted instead of being at right angles to plane in which it moves around sun.

b) That earth moves around sun.

Problems to Solve (p. 49). 1. This graph may best consist of two bar graphs with the proper fraction of each darkened to indicate the length of night.

2. When earth is in certain positions in its path around sun, region around North Pole is in such a position that it is lighted all around because of angle at which earth's axis is tipped. For same reason, at another position in earth's path around sun, polar region is dark all around and there is no change from day to night. Hammerfest is in this northern region and therefore has a period when there is no night and another period in which there is no day.

Self-Testing Exercises (p. 51). 1. Because earth is moving from west to east, sun appears first in east and later in west. If time is kept by sun, the sun is higher in places in east and therefore earlier than in west; thus time will be different.

2. The country has been divided into Standard Time Zones. All places in a zone have time of that zone. Each zone is based on longitude line, and there are 15 degrees of longitude in each zone. The meridian, or line, on which each zone is based is in the center of the zone. Passing from one zone to the next requires a change in time of one hour.

3. Because this country is so large that there would be many different times if every town were keeping its own time by the sun. This would of course be very confusing and lead to many difficulties in social and business matters.

4. Four time belts.

Experiment 4. How Does the Angle of the Sun's Rays Change from Day to Day? (p. 52). Materials and apparatus needed for the experiment are:

Classroom window where the sun shines in each day
Large piece of cardboard with a four-inch square cut from the center of it

Be sure the pupils understand that the light rays from the sun travel in straight lines. Have a committee responsible for checking and recording results as suggested in the experiment. The shape of the lighted spot changes from time to time. If the lighted spot gets nearer to the window, the sun is getting higher in the sky and the spot covers less area. If the lighted spot gets farther away from the window, the sun is getting lower in the sky, and the spot covers more area.

Experiment 5. How Does the Angle of the Sun's Rays Affect the Amount of Heat the Earth Gets? (p. 53). Materials and apparatus needed for the experiment are:

Two large, shallow cardboard boxes
Dry sand or soil
Two laboratory thermometers

Place the boxes where the direct rays of the sun can fall upon them but where they will not be exposed to wind or other unfavorable conditions. A twelve-minute exposure is usually long enough to get good results. A longer exposure may be necessary, but do not allow the boxes to stay in the sun until both absorb the maximum amount of heat.

Record temperatures at the beginning of the experiment (when they should read approximately the same) and at the conclusion. The "direct," or vertical, rays are hotter because a given amount of sunlight is concentrated upon a smaller space than when the rays are slanting.

Self-Testing Exercises (p. 55). 1. (a) Days are longer in summer; therefore more hours of sunshine to heat earth.

b) Our end of the earth's axis is inclined toward sun in summer; thus sun's rays strike our part of earth more nearly vertically.

c) Sun's rays pass through less atmosphere than in winter and therefore lose less of their heat before striking the earth's surface.

2. One form for this diagram is shown in Figure 3 below. Dotted lines are not called for by the exercise but are useful for reference. Some pupils may make the earth much smaller and show the sun in two positions or make two separate diagrams of the earth, one with the pole slanting toward the sun and the other with the pole slanting away. The essential facts, however, should be shown as indicated by this diagram.

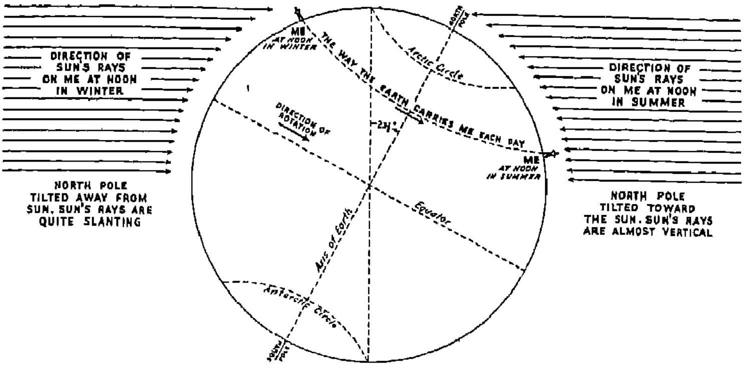
DIRECTION OF SUN'S RAYS ON ME AT NOON IN WINTER
NORTH POLE TILTED AWAY FROM SUN, SUN'S RAYS ARE QUITE SLANTING
ME AT NOON IN WINTER
THE WAY THE EARTH CARRIES ME EACH DAY
NORTH POLE
Arctic Circle
DIRECTION OF ROTATION OF
23½°
ME AT NOON IN SUMMER
Equator
Axis of Earth
Antarctic Circle
SOUTH POLE
DIRECTION OF SUN'S RAYS ON ME AT NOON IN SUMMER
NORTH POLE TILTED TOWARD THE SUN. SUN'S RAYS ARE ALMOST VERTICAL

FIG. 3. DIAGRAM TO SHOW THE DIFFERENCE IN ANGLES OF THE SUN'S RAYS ON A CERTAIN POINT ON THE EARTH'S SURFACE IN SUMMER AND IN WINTER

Problems to Solve (p. 55). 1. The diagram should be essentially the same as that shown for Self-Testing Exercise 2 above except that the place of reference would be in the southern hemisphere. In fact the two diagrams could be easily made together.

2. No. The sun is so nearly overhead all the time that it always stays quite warm except at high altitudes. However in many places the shifting position of the sun causes rainy and dry seasons.

3. No change of seasons. At any place on earth, sun would rise and set in same place and reach same height at noon. There would be different temperatures over the earth, but they would remain same for any given place.

PROBLEM 5: HOW DO ASTRONOMERS LEARN ABOUT THE HEAVENLY BODIES? (P. 56)

The light from heavenly bodies provides the only means by which astronomers have gained their vast stores of knowledge. The story of the development of this knowledge provides one of the most interesting phases of scientific history. This problem provides the basis for elementary knowledge of four of the astronomers most precise tools: (1) refracting telescopes, (2) reflecting telescopes, (3) mathematics, and (4) spectroscopes and spectrographs.

In addition to the material of this problem, such supplementary experiences as the following may well be utilized if time permits: (1) Let the children make a simple refracting telescope using two cardboard mailing tubes, one of which will just slide inside the other, any kind of cheap lens of as long focal length as can be had for the objective lens, and a lens of as short focal length as possible for the eyepiece. (2) The actual use of a prism to separate sunlight into its component parts. (3) Vaporizing in the blue flame of a Bunsen burner on the end of a piece of clean iron wire such common chemicals as table salt, copper sulphate, and cobalt chloride to show that each of these substances in burning has a characteristic color.

The following are the main ideas to be brought out in the study of the problem:

1. Light from heavenly bodies provides the only means by which astronomers can gain their knowledge of the stars and the other heavenly bodies.
2. Telescopes magnify heavenly bodies and make these bodies appear to be larger and nearer.
3. Most astronomical work is done by photography. A special kind of camera is used in connection with a telescope.
4. Astronomers use mathematical means for finding the distances to heavenly bodies.
5. The spectroscope and the spectrograph are used to determine the composition of stars.

EXPERIMENT 6. HOW DOES A REFRACTING TELESCOPE WORK? (P. 57). Apparatus and materials needed are:

Three ringstands with clamps
Paper screen
Reading glass
Magnifier (use a tripod magnifier or eyepiece of compound microscope).

This experiment may be operated profitably as a teacher demonstration, with each pupil focusing the apparatus and viewing the enlarged image which is obtained. Care must be taken to adjust the lenses and the screen to the proper height. It should be noted that an exhaustive study of lenses is not intended here. Merely carrying the work to the point where the pupils see that the objective forms an image that is magnified by the eyepiece is sufficient.

SELF-TESTING EXERCISES (P. 65). 1. A device for sighting stars and measuring the angles at which they were seen.

2. (a) Because they magnify the heavenly bodies near at hand and make it possible to see what could not otherwise be seen; (*b*) because they gather and concentrate the faint light from the stars.

3. (a) In a reflecting telescope light from object falls on a large concave mirror and is reflected from this. Since mirror is concave, light all comes to a point. Small flat mirror usually reflects light to an eyepiece at the side where observer sees image.

b) In a refracting telescope lenses instead of mirrors are used. There are two lenses, one called an objective lens and the other an eye piece. Light from object passes through objective lens and forms image which is magnified by eyepiece lens. (Diagrams illustrating these principles are on pp. 58 and 60 of the text. Pupil diagrams should be examined to see whether they indicate grasp of principles involved.)

4. *Distance to a body in solar system:* Two astronomers at different points sight the planet at the same time. By knowing the distance between the two points and the angles between this line and lines to the planets from the points of observation, the distance of the planet can be determined mathematically. *Distance to one of nearer stars:* Angle of star with earth is taken at interval of six months. Distance earth has traveled around sun in that time is known. With the two angles and this side, there is a triangle from which the distance to the star can be computed.

5. Kinds of materials found in stars. Light from star passes through prism of spectroscope, where it is broken up into its different parts. It is known that each element shows characteristic bright lines when it is vaporized and the light passed through a spectroscope. By comparing the lines in the light from the star with the known lines of the elements, the elements in the star can be determined.

PROBLEMS TO SOLVE (P. 65). 1. (a) Large mirrors that are usable are much easier to make than large lenses.

b) Tube for a very large refracting telescope would have to be exceedingly long and would be difficult to house and handle.

c) Lenses larger than 4 or 5 feet would probably bend under own weight and distort image.

2. (a) Arithmetic in solving problems of time and distance in light years, etc.

b) Geometry and trigonometry in determining distance by means of angles and known distances.

c) Principles of algebra used in working out many problems.

LOOKING BACK AT UNIT 1 (P. 66). 1. Responses will, of course, vary from pupil to pupil but should include most of the following: (a) Earth is a ball 8000 miles in diameter, composed of a solid part, a water part, and air.

b) Solar system is made up of sun, planets and their satellites, planetoids, comets, and meteors.

c) Moon shines by light reflected from sun and does not make its own light.

d) Moon appears to change its shape because it revolves around earth and we see different parts of its surface lighted by sun.

e) There is an eclipse of moon when earth is directly between sun and moon, of the sun when the moon is directly between the earth and sun.

f) Tides are caused by gravitational attraction of moon and sun on large bodies of water on earth.

g) All heavenly bodies have an attraction for other bodies.

h) Universe consists of solar system and stars, in fact, of everything that exists in space.

i) Astronomers believe that the sun, the whole solar system, and all stars we see at night are members of a great star group, or galaxy.

j) Stars appear to rise and set as sun and moon do because earth is turning.

k) Because earth is moving around sun, some constellations are seen at one time of year and some at other times.

l) Length of days and nights varies at different times of year because of tilting of axis of earth and revolving of earth around sun.

m) Since earth rotates from west to east, sun rises earlier in east than in west, and different places on earth have different times according to sun.

n) Position of earth in relation to sun as earth revolves around sun causes seasonal climatic change in different regions on earth.

o) By using very exact instruments and mathematics, astronomers are able to learn a great deal from the light of the heavenly bodies.

2. Answers vary with personal feelings of pupils.

3. A *star* is a heavenly body, like the sun, that gives out light itself because it is made of hot gases.

A *comet* is a heavenly body, made of hot gases, that travels around the sun in a very loop-shaped path.

An *orbit* is the path that any heavenly body takes in its journey around another heavenly body.

A *planet* is a solid heavenly body, like the earth, that travels in a regular orbit around the sun. Planets shine only by reflected light.

A *meteor* is a body of material that falls from somewhere into the earth's atmosphere, where friction makes it so hot that we can see it.

A *galaxy* is an enormous group of stars.

A *nebula* is an irregular-shaped mass of material, believed to be made up of other galaxies of stars.

An *eclipse* of the moon occurs when the earth passes in a direct line between the sun and the moon; an eclipse of the sun occurs when the moon passes in a direct line between the earth and the sun.

The *universe* consists of everything that exists in space.

A *sun-spot* is a large mass of whirling gas on the sun's surface.

The *latitude* is the distance north or south of the equator.

The *longitude* is the distance east or west of the prime meridian which passes through Greenwich, England.

A *meteorite* is a meteor that has fallen to the earth.

An *astrologer* is a person who attempts to foretell events on the basis of the positions of the stars.

An *astronomer* is a scientist who studies the stars and other heavenly bodies.

An *hypothesis* is the best explanation that can be given for observed or proved facts.

A *constellation* is a group of stars named because of imagined resemblance to an animal or some other object.

The *solar system* is made up of the sun and the other heavenly bodies that revolve around it.

Sun time is the time according to the sun. Noon is the moment when the sun is directly overhead or south or north of the observer.

Standard time is based on the time at certain meridians. All places within one-half hour's time east and west of each of these meridians have the time of that meridian.

ADDITIONAL EXERCISES (P. 66). 1. (a) After June 21 the temperature continues to rise because the earth continues to receive heat faster than it is radiated back into space. Not until late in summer do nights become long enough to allow as much heat to be lost as is received during the day. (b) For a few weeks after the 21st of December the earth continues to lose heat faster than it receives it from the sun. When the days begin to get longer so that more heat comes to the earth, the coldest days are over.

5. Distances of planets from post with scale of 1 in. = 36,000,000 miles: Mercury, 1 in.; Venus, 1.9 in.; Earth, 2½ in.; Mars, 3.9 in.; Jupiter, 13.4 in.; Saturn, 24.6 in.; Uranus, 49.5 in.; Neptune, 77.5 in.; Pluto, 102 in.

8. Some of the great telescopes of the world.

LOCATION	TYPE	SIZE
Harvard University, Station in South Africa	Reflecting	60 inch
Victoria, British Columbia	Reflecting	72 inch
University of Texas	Reflecting	82 inch
University of Michigan	Reflecting	85 inch
Mt. Wilson Observatory, California	Reflecting	100 inch
Mt. Palomar, California	Reflecting	200 inch
Lick Observatory, California	Refracting	36 inch
Yerkes Observatory, Wisconsin	Refracting	40 inch
Lowell Observatory, Arizona	Refracting	24 inch

9. Because the earth's axis is inclined at an angle of 23½ degrees. When the earth is in the position in which the polar regions receive sun, the whole area that is lighted extends 23½ degrees south of the pole. The parallel that marks the boundary of this area is the Arctic Circle.

10. Because the angle at which the earth's axis is inclined is 23½ degrees. On June 21 the vertical rays of the sun are the farthest north that they can get, and this is 23½ degrees north of the equator. This parallel is known as the Tropic of Cancer.

PAMPHLET FOR UNIT 1

Standards Circular 406. *Standard Time Throughout the World.* 5c

VISUAL MATERIAL FOR UNIT 1

As motion pictures, slides, filmstrips, photographs, charts, etc. contribute much toward making science instruction more meaningful to pupils, a few selections have been made for most of the units. In part Four, "Publications and Teaching Materials for the Science Teacher," there are lists of sources of these materials.

MOTION PICTURES

Encyclopaedia Britannica Films
  "Our Earth"
  "The Earth in Motion"
  "The Solar Family"
  "Exploring the Universe"
Society for Visual Education. "The Earth and Worlds Beyond"

PHOTOGRAPHS, SLIDES AND FILMSTRIPS

Lick Observatory, Mount Hamilton, California (photographs)
Society for Visual Education (filmstrips)
  "Rotation, Revolution, Consequences, Parts I and II"
  "Latitude and Longitude"
  "Moons, Planets, Comets, Star-clusters, Nebulae"
Yerkes Observatory (photographs and slides)
  Catalogue from University of Chicago Press.

CHARTS

Russell, James L. and Russell, David W. Series of articles in *School Science and Mathematics*, November 1939-June 1940. Monthly sky charts as well as helpful teaching activities in astronomy.

Standards Misc. Publication No. 155. (Map) *Standard Time Zones of United States and Adjacent Parts of Canada and Mexico.* 10c

UNIT 2

How Is the Force of Gravity Useful to Us?

FUNCTION AND SCOPE OF UNIT 2. This unit requires a rather careful study of gravity and its influence in the everyday lives of all of us. (The unit graph on page 81 will help show these influences more concretely.) It is significant (*a*) because of its close relations to everyday life, (*b*) because of the exact scientific laws it introduces, and (*c*) because it illustrates the fact that scientific study often brings many seemingly different things into clear relationships to one another. This last idea is brought out in an interesting way by Newton's discovery that the moon and planets are held in their paths by gravity.

Unit 2 grows naturally out of certain ideas the pupils will, in most cases, have met in Unit 1. In the first problem of Unit 1 the pupils learned that the spherical earth is surrounded by a layer of air and covered, over most of its surface, by deep water. In Problem 2 of Unit 1 they learned that the planets and other minor members of the solar system travel around the sun in approximately circular paths. They also learned that there is a mutual gravitational attraction between the members of the solar system that holds the planets and moon in place and causes tides.

The understandings developed in Unit 2 are helpful in Unit 3, "How Does the Earth's Surface Change?" and are practically essential for satisfactory study of Unit 4, "Why Do Some Things Rise and Others Sink in Fluids?" Unit 4 is, in turn, important in the development of the thought in Units 6 and 7.

INTRODUCTORY EXERCISES (P. 70). It should be noted that Introductory Exercises 1 and 2 are direct tests for material that pupils should remember if they studied *Science Problems, Book 1.*

*1. We mean that all materials are believed to be made up of many very tiny particles too small to be seen by even the most powerful microscopes. The behavior, arrangement, etc., of the molecules give the material its characteristics. (*Science Problems, Book 1,* pages 102-107.)

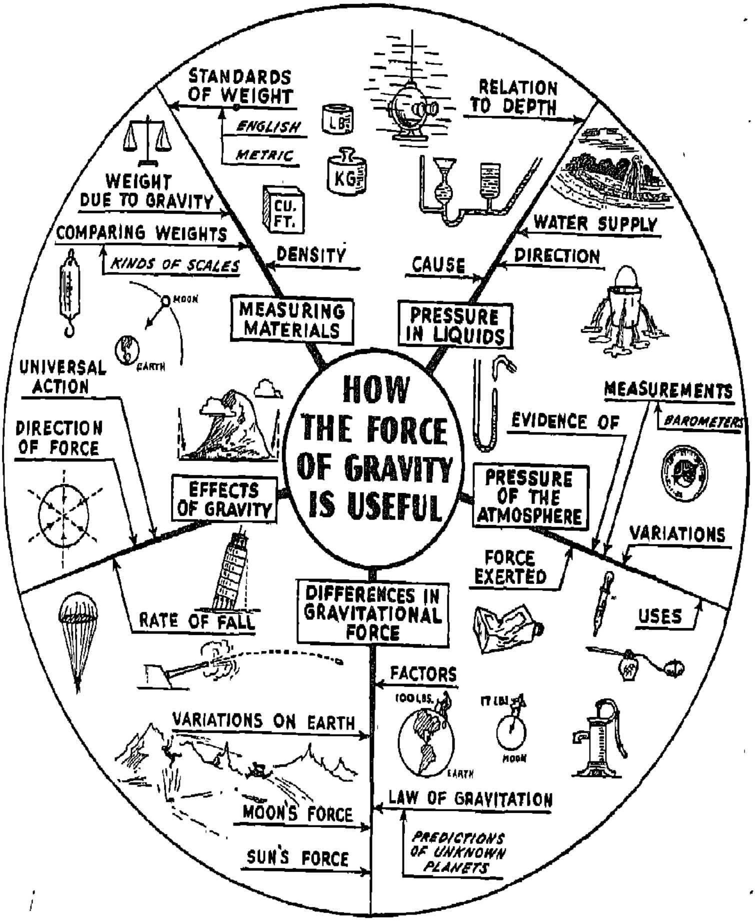

FIG. 4. GRAPH OF THE SUBJECT MATTER OF UNIT 2

*2. Squeeze most of the air from a basketball or a football, weigh it and record weight. Then pump ball full of air and weigh it again. Ball full of air weighs more than deflated ball. Since air is only material added, air must have weight. (*Science Problems, Book 1*, pages 82-83.)

3. Air resistance on feather makes it fall more slowly. In vacuum the two bodies would fall at same rate.

4. Gravity is exerting force on water in barrel. Any pressure in a liquid acts in all directions, sideways as well as downward. When a hole is made, the force caused by gravity, acting sideways, causes water to flow from hole.

5. So that air in ball will have same pressure as that on earth. Miles above earth the air pressure is greatly reduced and, if ball were open, balloonists could not get enough air into their lungs to keep them alive.

6. Pressure of water at that great depth would crush weaker walls and windows.

7. Both have gravity, that is, each is attracting the other, but earth is so much larger that we feel that the earth is really doing all the pulling. Actually, there is only one force, and that is due to action of both brick and earth.

8. Gravity is used in water systems and in clock pendulums. It keeps us and everything around us from flying off the earth. It makes the roots of plants grow down and the tops up. Pile drivers operate by gravity. Gravity pulling water through water wheels provides power for generators. Gravity helps us weigh things. It brings water through pipes to many homes, etc., etc.

9. Both struck at same time.

10. Used to indicate the pressure of the air. Barometers are useful because they indicate the coming of weather changes.

11. Answers individual with pupils. Gravity probably a factor in most of water systems used. Systems that have elevated reservoirs or standpipes use gravity directly to bring water down to faucets in houses and other buildings. All pumps that use air pressure are using the force of gravity.

12. Because of push of air on liquid outside straw. Some of the air is withdrawn from straw by mouth. Pressure of air on liquid in glass forces it up into the straw where pressure has been made less by mouth.

LOOKING AHEAD TO UNIT 2 (P. 71). Many pupils may be slow in getting interested in this unit because they feel that they understand almost all there is to be known about gravity. The teacher's introduction of the unit should be planned to eliminate such indifference by making pupils aware (*a*) of the many ways they use gravity, (*b*) of the many effects of gravity they have not known about or connected with gravity, (*c*) of the interesting facts and stories connected with gravity, and (*d*) of the mysterious nature of gravity.

Use of a number of the Introductory Exercises as class exercises or topics for discussion will often produce good results. When the pupils begin really to get interested, the teacher may give a brief talk that "points up" the discussion and leads right into the first problem; or he may have the pupils read the introduction provided in the textbook. The main ideas brought out in the introduction in the textbook are: (1) Gravity is responsible for many of the things we do or have happen to us. (2) What is gravity? How does it act? (3) Newton found gravity mysterious enough and important enough so that he studied it for many years and stated what he learned in a great "law" of science.

PROBLEM 1: WHAT EFFECTS DOES GRAVITY HAVE? (P. 73)

Problem 1 is an elementary analysis of action of gravity on bodies free to fall and of the direction of its action. Some of the ideas go directly contrary to common belief, and some are so novel that they may seem unreal. Yet both types of ideas are interesting to most pupils. The main ideas to be developed are:

1. Gravity pulls from all directions toward the earth's center.

2. If there were no air resistance, objects of all sizes would fall at equal rates, and gravity would make each one fall faster and faster the longer it fell.

3. Air resists rapidly moving objects and slows their fall. The air resistance increases as the area of the object gets greater and as the speed becomes greater.

4. An object moving horizontally is pulled down toward the earth just as fast as one that falls straight down.

5. Any two objects in the universe attract each other: The moon is constantly falling toward the earth; a plumb line near a mountain is really pulled over a little by the material in the mountain.

EXPERIMENT 7. HOW DOES GRAVITY ACT ON OBJECTS THAT ARE MOVING HORIZONTALLY? (P. 76). Apparatus and materials needed for the experiment are shown in Figure 59, p. 76. The apparatus must be perfectly level to obtain satisfactory results. If accurately made and level the sounds of the two marbles should be heard at the same time by a person equally distant from both.

SELF-TESTING EXERCISES (P. 77). 1. They all fall "down," that is, toward center of earth. Since earth is round, down is toward the center of earth in any position on surface or above surface. In one way this is "in the same direction" and in another way it is not.

2. Yes. Gravity pulls on the stone all the time it is falling, and the longer it falls the faster it goes.

3. No. Will fall faster and faster until it gets to point where air is pushing up on it just as hard as gravity is pulling downward. Then it cannot fall any faster.

4. A man without a parachute falls with ever increasing speed until he is falling at a speed of 120 m.p.h. or faster. When he strikes the ground, it is with such a tremendous force that he is killed. A parachute, however, offers a large surface to the air, so that man and parachute fall slowly and strike the earth gently.

5. By dropping a large weight and a small one from top of tower at same time and showing that they both reached the earth at same time.

6. Yes.

PROBLEMS TO SOLVE (P. 77). 1. In doing this experiment the lid is to be released so that it falls in a horizontal position. Of course, if both fall separately the lid falls much more rapidly. When the feather falls "behind" the lid, all the air resistance is exerted against the lid and the feather falls as fast as the lid.

2. When bullet reaches ground, its speed is less than when it left gun because air resistance causes it to fall more slowly.

3. Gravity pulls weight toward center of earth in a straight vertical line. String attached to wall and weight marks the straight line, and the brick layer can follow this line knowing that it is straight and vertical.

4. Because of gravity the bullet will fall to the ground in a certain length of time. The faster a bullet travels the farther it can go in that time. The air slows the bullet down. Therefore, it cannot travel so far as it would without air in its path.

SELF-TESTING EXERCISES (P. 80). 1. Diagram based on Figure 61. This exercise is usually done most effectively in class as a class test after the pupils have made adequate preparation. The results may then be discussed by the entire class.

2. Gravity is pull of the earth on other bodies of matter. Gravitation is attraction that all bodies have for one another.

3. The pupil should describe the experiment with plumb lines and the mountain, page 79.

4. "Any two objects in the universe attract each other." (Pupils will be on the lookout for the other part of this law. Let them find its statement themselves.)

5. (a) Attraction of a body passing near sun tore large masses of gaseous material from sun.

b) Attraction of body that became the earth, for other bodies passing near it caused these bodies to come toward the earth and finally become part of it.

PROBLEMS TO SOLVE (P. 80). 1. Too slight to be felt except with finest instruments.

2. (a) Earth and moon as well as other members of solar system would each go on in a straight line. Thus, there would be no solar system as we know it now.

b) Things would fly off from surface of earth as it whirled swiftly around. Earth itself would probably fly into bits.

c) No air around earth; no winds or rain falling on earth.

d) Water would not run down hill, and there would be no waterfalls as a source of power.

3. Yes. Because of tides in ocean, which are caused by attraction of moon for earth. Moon is pulling on whole surface, but since

solid parts are less easily moved than water, we see effect only in large bodies of water (pp. 30-31).

4. See Figure 61, page 78.

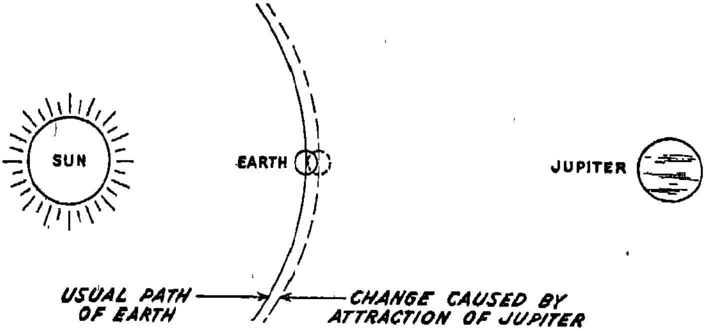

FIG. 5. DIAGRAM FOR PROBLEM 5

5. One way of drawing this diagram is shown in Figure 5. The essential relations should be similar in all such diagrams.

PROBLEM 2: HOW DO WE USE GRAVITY TO MEASURE MATERIALS? (P. 81)

Study of this problem should make clear to the pupils that weighing things is in reality comparing the pull of gravity on them with its pull on standard bodies (pounds and kilograms). It also introduces the two systems of standards and substitutes the more exact term density for lightness or heaviness of materials. The value of each of these concepts both for general information and as tools is obvious. The ideas of the problem are more specifically stated as follows:

1. We weigh an object by finding how hard gravity pulls on it.

2. To weigh anything, we must have a standard amount of pull, a unit, and a device for comparing the pull of gravity on two things. Scales and balances compare gravitational pulls by using levers or springs.

3. Civilized nations have very carefully made standard weights. Two standards and subdivisions are used—the pound and the kilogram.

4. To avoid confusion, scientists call the heaviness of a material, *density*. The density is the amount of matter in a certain space, as pounds of water in a cubic foot.

SELF-TESTING EXERCISES (P. 86). 1. Gravity pulls on all materials. This fact is used to weigh things, since we can compare pull of gravity on an object of unknown weight with pull on some standard object whose pull is known. The standard is determined by selecting something of definite size and material and giving the amount of pull on this object a name, such as a *pound*, a *stone*, or a *kilogram*.

2. Springs can be overstretched so that they lose their correct shape and fail to weigh accurately. They are also affected by changes of temperature.

3. (a) System based on kilogram.

b) Used by scientists everywhere and by most countries except Great Britain and U.S.A.

c) A decimal system. Its other units are easily determined because all that is necessary is to move the decimal point to indicate the proper multiple of 10.

4. The kilogram.

5. Amount of material in a certain space. Density of water is 62.4 lb. of water in a cubic foot of space. Mercury has 849 lb. per cubic foot; gasoline, 42 pounds; lead, 705 lbs.; cork, 15.6 lbs.; ice, 57.2 lbs.; iron, 486.7 lbs. (Density may also be given in pounds per gallon as in Figure 67, page 87.)

PROBLEMS TO SOLVE (P. 87). 1. Divide the number of pounds you weigh by 2.2 to determine the number of kilograms you weigh. (See Table 2, page 85.)

2. Table 2 gives one gram as 1/28 ounce. Sixteen ounces would then be 16 ÷ by 1/28 (16 × 28) grams, or 448 grams. Actually, 1 oz. = 28.35 grams, which makes the 453.6 grams per lb. usually given as the number of grams in a pound.

3. Pupils should be encouraged to analyze the scales down to their essential levers and omit accessory parts. Different types of scales can probably be studied at local meat, grocery or feed stores.

4. Densities of some common materials, in grams per cubic centimeter are given in the table on the next page. (Pupils' answers may be of different materials and given in different units.)

MATERIAL	DENSITY	MATERIAL	DENSITY
Platinum	21.5	Aluminum	2.65
Gold	19.3	Water	1.00
Mercury	13.6	Ice	0.9
Lead	11.4	Alcohol	0.79
Silver	10.5	Gasoline	0.75
Copper	8.93	Cork	0.2
Iron (Cast)	7.4	Air	0.0012

5. Metric density of water is 1. Weight of 1 cc. of water at 4° C. is 1 gm. Since densities of other materials are always compared with water, it is easy to find out how much heavier a material is than water, when the number is divided by 1, rather than by some other number.

6. (a) Weigh the block of wood or stone.
b) Find volume of block by measuring and calculating.
c) Divide weight by volume to find density.

PROBLEM 3: HOW DOES GRAVITY AFFECT LIQUIDS? (P. 88)

Visualization of any body of fluid as a mass of columns in which one cube is set on top of another from bottom to top will prove illuminating in any situation which involves use of the concept of the pressure inside or beneath fluids. The force acting in any column can then be easily pictured as the total weight of all the cubes in the column. Ability of pupils to do this kind of visualizing should be the teacher's objective in the study of Problem 3. The subsidiary ideas are as follows:

1. Inside a body of liquid, gravity causes pressure that acts in all directions.
2. At any point beneath the surface of a liquid the force per square foot is equal to the weight of all the water pushing straight down on that square foot; the pressure increases with the depth.
3. The shape of a vessel does not affect the pressure; thus, in all open parts of a connected system a liquid rises to the same level.

4. The preceding principles make water flow from faucets in many water-supply systems even though the water may enter the system many miles away.

EXPERIMENT 8. IN WHAT DIRECTION DOES WATER EXERT FORCE? (P. 88). Apparatus and materials needed for the experiment are:

Tin can or bucket at least one foot deep
Medium-sized nail
Block of soft wood to hold against can while making hole
Soft wood plug of same diameter as nail (match stick)
Hammer
Water to fill the can
Second tin can of at least one-pint capacity, preferably larger
Large pan or sink should be available to catch water that squirts from larger container

The directions for this experiment are clear. If the hole is carefully made, the stream of water from the large can should be approximately like one of the streams shown in Figure 69, page 89. Inside the small can the pupils should observe that the water squirts straight upward. Since the same thing happens no matter where we make the hole or place the small can, the water near the surface must be pushing in all directions.

EXPERIMENT 9. HOW DOES THE PRESSURE OF WATER CHANGE WITH THE DEPTH? (P. 91). Apparatus and materials needed are same as in Experiment 8 except for the small can. Two more wooden plugs (match sticks) will be needed.

Be careful that the holes are the same size and made with the nail held perpendicular to the side of the can. The results should be approximately as shown in Figure 69, page 89. The lower the opening is the harder the water squirts out, thus indicating that "pressure increases with depth." The pupils may, of course, say the same thing in many different ways.

SELF-TESTING EXERCISES (P. 93). 1. Liquid has weight. At any place below surface weight of liquid above that place makes pressure.

2. Water is pushing up as well as sideways and down.

3. The deeper he goes the more water there is above him and the greater the weight of material on him, or, in other words, the greater the pressure of the water on him.

Problems to Solve (p. 93). 1. Pressure at bottom of first dam will be same as that of second dam. Depth of water is same in the two cases; so pressure will be same. Length of lakes makes no difference.

2. Pressure of water is so great at depth of six miles that a submarine would be crushed if it were to attempt to go down to this depth.

3. (a) Tank 1 ft. deep = 0.43 lb. (from page 91, or 62.4 ÷ 144).

b) 3 ft. deep = 1.3 lb. (.43 lb. × 3 or 62.4 × 3 ÷ 144).

c) 90 ft. deep = 39 lb. (.43 lb. × 90 or 62.4 × 90 ÷ 144).

4. 1361.5 lb. per sq. in. (64.75 × 3028 ÷ 144).

5. 19.06 tons (answer of problem 4 × 28 ÷ 2000).

6. Pipe of well is at base of a long slope. Water enters stratum at top of slope, and gravity carries it down. At bottom of slope the pressure of water is great enough to force water up pipe without being pumped.

Self-Testing Exercises (p. 98). 1. The essential features of this diagram are a reservoir of any kind above the level of the houses to be supplied and a pipe leading to the location of the faucets. Various ways of filling the reservoir might be included.

2. Both New York and Los Angeles get water from large reservoirs at some distance from and above level of city. Gravity brings water down from one reservoir to another and finally to city. Highest reservoirs are filled by mountain streams.

3. The diagram called for may be some variation of the arrangement shown in Figure 77, page 97, or Figure 80, page 99.

4. As shown in the preceding sub-problem, the pressure in water becomes .43 lb. per sq. in. greater for every foot of depth below the surface. The first floor faucets are about 30 feet farther below the surface of the water in the reservoir than those in the fourth floor. Any answer that shows a reasonable understanding of this principle is acceptable.

5. Pressure that would be great enough to force water up into top floors would be too great for pipes of lower floors. Therefore necessary to have several systems at different levels so that all floors will have enough pressure but no floors will have too much.

Problems to Solve (p. 99). 1. Because pressure of the water is much greater on lower part than on upper. Pressure always increases with depth.

2. No difference in amount of pressure. Pressure is same since height of water is same in tanks. Pressure is independent of shape.

3. 93 ft. To force water up one foot requires .43 of a pound of pressure per square inch. Forty pounds per square inch will force the water 40/.43 feet, or 93 feet.

4. Height of oil in tank and density of oil.

5. This diagram may well follow the plan of Figure 78 or Figure 80 with whatever changes are needed to make it fit the local situation. If at all possible, the class should visit the local water-supply system, or a committee may make the visit and report to the class.

PROBLEM 4: HOW DO WE USE THE PRESSURE OF THE ATMOSPHERE? (p. 100)

The principle of atmospheric pressure is one of the scientific principles most commonly used by the average person and one of the most commonly misunderstood, especially in situations where its action is designated as suction. The development in the textbook is planned to give an understanding of the real nature of atmospheric pressure and also teach the principle of the manometer, that is, the automatic balancing of pressure against a column of liquid in order to measure the pressure.

The fact that air has weight should be reviewed by discussing ways in which it can be demonstrated or by actually doing such an experiment in case many of the pupils have not seen such an experiment. The main ideas of the problem are:

1. Gravity, pulling on all the air above the earth's surface, causes a great pressure which tends to force air into all empty spaces near the earth's surface.

2. The actual pressure of the atmosphere is measured by balancing it against a column of mercury in an evacuated tube.

3. As one goes higher in the air, the pressure becomes less because there is less air above to be pulled down by gravity.

4. Tests show that the atmosphere really exerts a tremendous force on all ordinary surfaces even though the barometer indicates a pressure of only fifteen pounds per square inch.

5. Many common devices use atmospheric pressure by reducing the pressure inside a closed space (creating a partial vacuum) and allowing the air to force something into it.

EXPERIMENT 10. WHAT WILL THE PRESSURE OF THE ATMOSPHERE DO TO AN EMPTY CAN? (P. 105). Apparatus and materials needed are:

One-gallon varnish can (smaller one may be used)
Air-tight stopper for can
Source of heat for boiling water in can
Cold water

The directions are easily followed and the demonstration almost never fails.

EXPERIMENT 11. HOW DO MAGDEBURG HEMISPHERES ACT WHEN THE AIR IS PUMPED OUT OF THEM? (P. 106). The apparatus needed: A pair of Magdeburg hemispheres and a vacuum pump. A little vaseline may need to be spread on the edges of the hemispheres to make the joint air-tight. An imitation of the original Magdeburg experiment is easily arranged with a team of pupils on each side.

SELF-TESTING EXERCISES (P. 108). 1. Unequal air pressure. Since there is no pressure on side from which air has been removed, pressure on other side pushes down on mercury and forces it up in empty side.

2. Goes down. Air pressure on top of high building is less than on ground. Air thus cannot hold up so long a mercury column.

3. Description of experiments with varnish can and with Magdeburg hemispheres.

4. (a) Answers will vary with different localities. The pressure is equal to the barometer reading in inches multiplied by .49 lbs. (See page 107 of text.)

b) By measuring the height of the mercury in a barometer.

5. (a) Aneroid barometer registers air pressure without use of column of mercury. As pressure of air increases or decreases, sides of a metal vacuum box move in and out. This movement is transferred to a pointer that moves back and forth on face of instrument and indicates changes on numbered scale.

b) Aneroid barometer more compact than mercury barometer and can be carried about more easily since there is no danger of breaking tube and losing mercury and of getting air in tube.

6. An especially designed aneroid barometer used by aviators to show altitude by measuring decrease in air pressure as they go up.

7. Air is easily compressed, and at sea level the weight of all the air above is pressing on the lowest region of the air, forcing the molecules closer together.

8. Less air in a cubic foot, and one can get less in his lungs at one breath.

PROBLEMS TO SOLVE (P. 109). 1. (*a*) It would rise in accordance with size of vacuum tube rather than stop at certain height regardless of size of tube. (*b*) As long as vacuum was there to exert a pull, mercury would remain in same position and not move up and down in response to changes in air pressure. (*c*) Changes in elevation would not affect the mercury column.

2. These inches correspond to height in inches to which column of mercury rises or falls in response to changes in air pressure. Ordinary aneroid barometers record only 26-31 inches, because ordinary changes of pressure occur only within this range.

3. 408 in. or 34 feet (30 inches × 13.6).

4. 76 cm. (30 × 2.54 cm.).

5. 5292 tons (40 × 125 × 144 × 14.7 ÷ 2000).

6. 5115.6 tons (40 × 125 × 144 × 14.21 ÷ 2000).

7. In mercury thermometer rise and fall of mercury is due to fact that mercury expands and contracts as temperature changes and mercury occupies more or less room. In barometer the rise and fall is due to change in weight of air pressing on column of mercury.

8. Reading would be a little lower because air on vacuum side would exert some pressure and prevent column from rising as high as it would if there were a vacuum.

9. Yes. Pressure on surface would remain same, and since mercury is a liquid, it will "seek its own level" regardless of shape of tube.

10. 19.05 tons (18 × 144 × 14.7 ÷ 2000).

EXPERIMENT 12. HOW DOES A SUCTION CUP USE ATMOSPHERIC PRESSURE? (P. 110). The only apparatus required is the rubber sink pump which may usually be obtained at small cost in a ten-cent store or a hardware store. It is also well to have on hand a few of the smaller suction cups on darts, coat hooks for car windows, etc.

These devices work as they do because expelling air from the inside and then expanding the cup again makes a much lower pressure on the inside than on the outside. A pull must be more than equal to the difference between the total forces to pull the cup off a smooth surface. For the practical use of the sink pump see the answer for Self-Testing Exercise 1 (*a*) on this page.

EXPERIMENT 13. HOW DOES A MEDICINE DROPPER USE ATMOSPHERIC PRESSURE? (P. 110). The apparatus and material needed are: a medicine dropper, water, and a container for the water.

Water rises into the tube of the medicine dropper because forcing some air out and then allowing the bulb to expand reduces the inside pressure to a point below that on the outside. The water is then forced into the tube. (See answer for Self-Testing Exercise 1 (*b*) on this page.)

EXPERIMENT 14. HOW DOES A VACUUM-CLEANER WORK? (P. 116). The only requirement for this experiment is a vacuum-cleaner, preferably in working order. The school janitor probably has one that he will loan the class. Figure 96 will help analyze the action of the cleaner, although a number of cleaners have a slightly different arrangement of the fan.

SELF-TESTING EXERCISES (P. 118). 1. (*a*) When cup is pressed over pipe or drain to be cleaned, some of the air is forced out from under cup. Greater air pressure on outside holds cup tight over opening. The greater air pressure down in the pipe forces water and waste from pipe up where there is a partial vacuum.

b) When rubber bulb on medicine dropper is squeezed, air is forced out from bulb and partial vacuum is created in it. Air pressure on liquid surrounding dropper pushes water up into dropper.

c) Air pressure on water in well pushes water into pump after air has been removed from pump cylinder by action of pump piston.

2. Atmospheric pressure is not great enough to force water up into a vacuum any farther than 34 feet.

3. Whirling blades throw air or water away from center of pump casing and create a partial vacuum. Atmospheric pressure forces water up into casing, while water thrown from center flows out another pipe.

4. Centrifugal air pump throws air out into a cloth bag. This leaves partial vacuum at center of the pump. Atmospheric pressure forces more air in through nozzle, and when nozzle is against a rug, air moving up through it carries dirt, etc., from rug into bag. Dirt remains in bag, and air goes on through.

PROBLEMS TO SOLVE (P. 118). 1. Lists will vary. May include some things named in the textbook. The class may enjoy making a class list. Medicine droppers, pumps, fountain pens, vacuum-cleaners, soda straws, water fountains for chickens, some kinds of ink wells, etc.

2. If there is a partial vacuum between lid and contents of jar, pressure of atmosphere outside would press on cap and help seal it.

3. Pressure of air on cardboard (about 15 lb. per sq. in.) holds it to tumbler. Air has been driven out by water in tumbler; thus there is unequal air pressure between outside and inside of glass.

4. When dry, the two may seem to stick together for a short time until air can enter space between them. When glasses are wet, space between them is occupied by water instead of air. Air cannot enter and pressure of air on outsides of glasses presses them together.

5. Partial vacuum in top of medicine dropper. Pressure of air on bottom of dropper is greater than that at the top. Water is held in by this greater pressure.

6. If the well is very deep, atmospheric pressure will not force the water high enough to reach the cylinder if it is above ground. (Air will push water up only about 34 ft.)

7. When door is pulled open rapidly, partial vacuum is created near that door. Air from the rest of the room moves in to replace it, making a lower pressure in the whole room. Normal pressure on outside then forces swinging door inward.

8. When the air pressure is high. Partial vacuum is created in front of propeller blades, and pressure behind the blades pushes them forward. If pressure is higher or greater, there will be more force on the blades, and the plane will move forward more rapidly. The same change will also give the wings a greater push upward. (See Figure 97, page 117.)

PROBLEM 5: HOW DOES THE FORCE OF GRAVITATION DIFFER AT DIFFERENT PLACES? (P. 119)

This problem differs greatly from the preceding one in having few if any practical applications for the average person other than giving him a better understanding of the universe. However, it will usually be found that pupils are interested in imaginary trips to various parts of the solar system and in finding how conditions would differ because of varying gravitational forces. The main ideas are:

1. The gravitational force between any two bodies depends on three factors: the amount of matter in each of the two bodies and the distance between their centers.
2. By applying this "Law of Gravitation" scientists know that the weight of any object on the moon is much less than on the earth, while on such a large body as the sun it is unbelievably greater.
3. Undiscovered planets have been located with the help of calculations based on knowledge of this law.

SELF-TESTING EXERCISES (P. 122). 1. (a) You could jump 10 or 15 feet into the air. You could lift great weights that you couldn't lift here.

b) Because the force of gravity is much less on the moon than on the earth, since the moon is much smaller than the earth.

2. How much material there is in each of the two bodies and the distance between the centers of the two bodies.

3. The center of the earth is nearer the ton of matter in some places than in others. The motion of the spinning ball causes it to flatten at the poles and bulge out at the equator, thus the surface is nearer the center at the poles than it is at the equator.

4. On the moon, the box of candy is so much nearer the center of the moon than it is to the center of the earth when on the earth's surface. The pull on the box would be 13/80 of 5 lb. or 13 oz., which is nearly a pound.

PROBLEMS TO SOLVE (P. 123). 1. (a) You would seem to weigh the same as on the earth, because the gravitational pull would be proportionately less on all the weights.

b) On spring scales you would weigh only 13/80 of your earth weight. Spring scales indicate the actual pull; they do not compare weights as do scales that operate by weights and levers.

2. Law of universal gravitation states that every material thing in the universe attracts and is attracted by every other material thing with a force that varies directly with the product of their masses and inversely as the square of the distance between their centers.

3. Mass means quantity of matter in a body. Weight means pull of gravity on the body. Mass remains same, but weight changes.

LOOKING BACK AT UNIT 2 (P. 123). 1. Each paragraph should include most of the main ideas listed at the beginning of the corresponding problem in this *Guidebook.*

2. *Gravity* is the pull of the earth on any object near it.

Gravitation is the attraction that all bodies of matter have for all other bodies. (Gravity is a special case of gravitation.)

An *altimeter* is a special kind of aneroid barometer used to indicate altitude for measuring the air pressure.

A *kilogram* is a standard amount of matter; it is equal to 2.2 lb.

A *gram* is 1/1000 of a kilogram. There are about 28 grams in an ounce.

Density is the amount of matter in a certain space, as pounds of water per cubic foot or per gallon.

Atmospheric pressure is the pressure on things in the atmosphere caused by the pull of gravity on all the air.

Centrifugal force is the force caused by the tendency of matter to fly outward when it is moving in a curved path.

A *barometer* is any instrument for measuring the pressure of the atmosphere.

A *partial vacuum* is a space that contains less air than is usual for that altitude.

An *aneroid* barometer contains no mercury or other liquid.

A *scale* or *balance* is some kind of device for balancing the gravity of standard weights of matter against that of unknown amounts of matter that we want to measure.

ADDITIONAL EXERCISES (P. 123). 1. Partial vacuum at top of can of water. Thus there is unequal pressure between air inside and air outside. Greater pressure on air outside keeps water in outside pan from running over.

3. Can may be forced into water to different depths to see how fast water comes in through hole in bottom.

4. One way would be to arrange tube something over 34 feet long with valve in both ends. To start barometer, put lower end in tub or barrel of water and close lower valve. Then fill tube from upper end, close upper valve, and open lower valve.

6. Hand feels as if it were being forced into opening. This is really true, because atmospheric pressure is much greater on outside than on inside.

7. Balloon is forced into flask and blown up inside. Air pressure from the outside blows up balloon in the partial vacuum caused by the condensing steam.

8. When atomizer bulb is pressed, strong current of air is blown across tube that goes down into the liquid. This drives some of the air away from above the tube, creating a partial vacuum. Air pressure on liquid in bottle drives liquid up tube and out of it. Air driven across it by squeezing bulb breaks it up into fine particles.

9. When water levels in two vessels are same, water stops running into vessel that was empty at first. Siphon will start again when one of vessels is again higher than the other.

10. Atmospheric pressure on the surface of the water in pan pushes water into jar because partial vacuum was created in jar when it was filled with water and then lifted partly out of pan.

PAMPHLETS AND BULLETINS FOR UNIT 2

Instrument Division. Circular F. 5th Ed. *Barometers and Measurement of Atmospheric Pressure.* 15c

Standards Misc. Publication 64. *History of Standard Weights and Measures of the United States.* 15c

VISUAL MATERIAL FOR UNIT 2

MOTION PICTURES

Encyclopaedia Britannica Films

"Atmospheric Pressure" "Water Supply, New York"

CHART

Standards Misc. Publication 3. *International Metric System.* 28×44 in. 40c

UNIT 3

How Does the Earth's Surface Change?

FUNCTION AND SCOPE OF UNIT 3. Units 1 and 2 have provided the pupils with an excellent orientation for the study of this unit. Unit 1 provided a brief survey of the universe, including one of the possible ways in which the earth might have originated, and a study of some of its more important physical features. Unit 2 supplied ideas of the gravitational effects of heavenly bodies upon each other, and of the earth's gravity upon bodies on the earth. Unit 3 is a more detailed examination of the surface of the earth and its changes, many of which are due to the action of gravity.

This unit deals with geologic processes whose effects are immediately apparent in the environment of the pupils—erosional features, formation of soil, streams, lakes, rivers, caverns, and mountains, the presence of fossils, and the kinds of rocks which are to be found. The processes of degradation, transportation of earth materials, aggradation, volcanism, and diastrophism are developed in a simple, understandable manner in showing how the earth's surface changes. Refer to the graph on page 100 for a general picture of the material to be studied in this unit.

In planning for the presentation of this unit, the teacher should keep in mind that a knowledge of these processes and their effects is not only an important part of the "world picture" of a well-educated person but is also of great practical value in helping him understand his surroundings. The ideas developed here are essential in understanding the need for and practice of soil conservation. Since this is true, there should be much supplementing of the text with illustrative material from the local environment. This kind of procedure calls for as much field work as is practicable for the class, with carefully directed observations and the collection of specimens such as various kinds of soils, rock, and minerals.

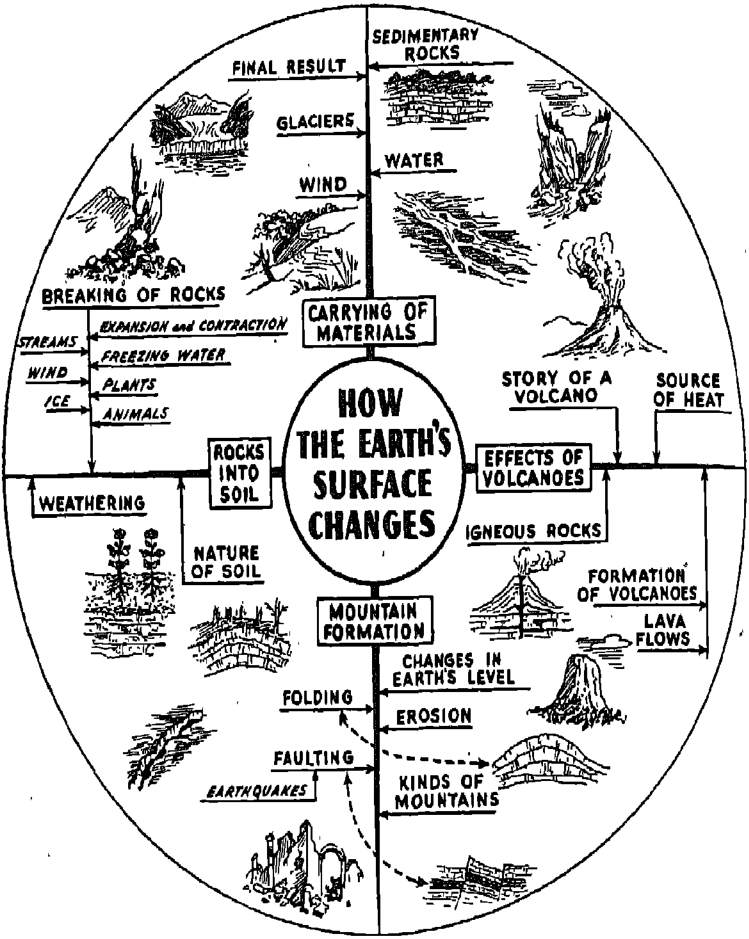

FIG. 6. GRAPH OF THE SUBJECT MATTER OF UNIT 3

INTRODUCTORY EXERCISES (P. 126). 1. Broken rock ground fine in various ways, and decayed remnants of plants and animals.

*2. Any characteristic of a material may be changed when it undergoes a chemical change. Examples are: color, odor, brittleness, hardness, ease of dissolving, melting point, ability to react chemically with other substances, poisonous or non-poisonous effect, etc.

*3. Expands.

4. By wind, by water, and by glaciers. Movement by man and animals may well be mentioned. Water probably most important.

5. (a) Make soil in rocky regions.

b) Hold soil.

c) Add to the soil and make it more fertile.

d) Hold water, thereby preventing excess water from running off and causing erosion.

*6. A liquid in which some other substance has been dissolved. Water gradually dissolves and carries away the materials in rock.

7. Layers of rock of kind made by deposit of materials in water. Remains of sea animals and plants in places now remote from any seas.

8. Rock melted by high temperatures inside earth.

9. Plain formed along bank of a river. River overflows its usual banks and leaves material in flat regions at sides.

10. No. Forces of wind, water, etc., have been wearing them away. Oldest mountains are now worn so that they are rounded and not very high. Youngest mountains are sharp and craggy because not worn away. Violent movements of earth also change their formation from time to time.

11. Wearing away of rock and soil by forces of wind and water. Important to many farmers because much of their best soil often is carried from fields by erosion. Soon the fields become very infertile because so much of the rich topsoil is lost.

12. May include erosion by wind and water; man-made changes, such as damming streams, etc.

13. By the dissolving and carrying away of soluble rock (usually limestone) by water penetrating the rock.

LOOKING AHEAD TO UNIT 3 (P. 127). The purposes of this part of the unit are (1) to arouse interest, (2) to provide a partial picture of the material which is to follow, (3) to introduce the work of geologists as a special branch of science, and (4) to make the pupils aware that the earth's surface is constantly changing.

These purposes may best be realized by the teacher's becoming acquainted with local geological features and with the geological processes whose results are most striking in the immediate surroundings. Present the introductory material in the form of a story by telling it to the class, or have the story read in class. Then draw upon the local environment for varied supplementary illustrations. Such procedures will help the pupils feel a need for learning more about their environment and will establish the precedent of applying, whenever possible, the main ideas of the unit to local conditions.

PROBLEM 1: HOW ARE ROCKS CHANGED INTO SOIL? (P. 130)

There is little resemblance between soil with its finely divided particles and solid rock masses. It is often taken for granted that pupils of the junior high school level see the relationship between these two forms of earth materials. To avoid this unjustified assumption, the problem begins with an analysis of soil to determine what materials compose it and then shows the kinds of processes which are responsible for soil formation. The relation of this problem to the question raised by the title of the unit should be made clear by showing that as rocks are changed into soil, the surface of the earth changes both in appearance and character. The slowness of change should be stressed to make the material more readily understandable.

The main ideas to be developed in the problem are:

1. Soil is rock material which has been separated into fine particles by means of natural processes.

2. Common kinds of soils are sandy soils, clay soils, and loamy soils.

3. Rocks in contact with the air and water are softened by means of chemical changes. These changes are known as weathering.

4. Expansion and contraction during changes of temperature and the freezing of water in cracks help break rocks.

5. Plants aid in the breaking of rocks by mechanical means and by chemical reactions.

6. Decaying plants form an important part of soil.

Experiment 15. What Are the General Characteristics of the Soil Where You Live? (p. 130). Apparatus and materials needed for the experiment are a tool for digging into soil and three glass jars for collecting samples of soil.

The edge of an eroded area, a ditch bank or roadbed cut, or other similar places provide ideal conditions for studying the types of soil at varying depths. If such features are not to be found, have the class use a posthole digger and make the analyses suggested in parts *a*, *b*, and *c* of the experiment as the excavation is done. Require the class to keep careful records in the field. Take specimens of soil at depths of four inches, eighteen inches, and three feet.

In the classroom, have the pupils prepare an exhibit of the specimens by displaying them in glass jars. Take enough soil (parts *a* and *b*) for Experiment 16, also. Have the answers to the questions asked by the experiments printed on cards to accompany the exhibit. The answers will vary with different localities and with different places in a given locality. Be sure that the pupils distinguish clearly between topsoil and subsoil.

Experiment 16. What Materials Can Be Recognized in Soil? (p. 131). Apparatus and materials needed are as follows:

Deep glass jar
Specimens of soil from parts *a* and *b* of Experiment 15
Window-pane glass or white paper
Magnifier or low power of compound microscope
"Tin" can lid
Bunsen burner or other heat source.

a) The heavier particles settle first. The material will be distributed in this order: rock particles (if any are present), sand, clay, organic material.

b) The results will vary with the soil samples used. Have the pupils list the kinds of materials present as they are identified. If the teacher wishes to extend the scope of this experiment, he should secure an inexpensive soil-testing kit which is simple enough of operation for pupils of this level. Many seed companies keep such kits in stock.

c) Be certain that the sample of soil is heated thoroughly to assure burning of organic material. Usually the color changes suggested in the directions are quite noticeable.

SELF-TESTING EXERCISES (P. 135). 1. Top layer of material on earth's surface, made up of broken and ground-up rock and organic material. Directly or indirectly our whole food supply depends on the soil.

2. Sand, clay, and humus.

3. Less humus than topsoil. Plants need the materials provided by the decaying plant and animal material found in topsoil.

4. (a) *Sand:* Does not hold water well. Well aerated. (*b*) *Clay:* Holds water in great amounts. Contains valuable minerals. Not well aerated. (c) *Loam:* Contains both clay and sand, as well as humus. Has needed organic matter. Well drained but holds enough water.

5. Decayed and decaying plant and animal material. As it decays, it provides minerals necessary for plant growth. It also provides chemical substances that help dissolve the useful minerals in clay.

6. Soil material made up of very fine particles. It holds great amounts of water and packs together very tightly when dry. Formed by destruction of rocks.

PROBLEMS TO SOLVE (P. 135). 2. To test water-holding capacity of soil: (a) Tie pieces of thin cloth over tops of three lamp chimneys and set chimneys upside down in dishes or better, support them on ring stands over tumblers.

b) Fill one chimney half full of sand, one of clay, and one of loam.

c) Let students pour a cup of water into each of the three chimneys at same time and watch to see through which one water runs first and which one allows most water to run through into tumbler.

3. (a) Take sample of soil and weigh it in a metal container.

b) Put sample over burner and heat red-hot until soil has blackened and then changed to lighter color. Allow this to cool and weigh again. Loss in weight will indicate amount of humus lost by burning. Remaining material is sand and clay.

c) To determine amount of sand and clay, stir the sample in a large volume of water in jar or graduated cylinder. Give the sand time to settle to the bottom. Pour off top liquid. Repeat until the water remains quite clear. Allow sand to dry and weigh it. Subtract this weight from weight of material left after burning off humus to find amount of clay.

EXPERIMENT 17. HOW DOES STONE THAT HAS BEEN EXPOSED TO WATER AND AIR DIFFER FROM PROTECTED STONE? (P. 136). Apparatus and materials needed are:

Specimens of weathered stones from fields, streams, and from underneath the soil
Knife
Hammer

Crumbly shale, "rotten" sandstone, and weathered limestone show well the effects of weathering. Break the specimens and examine the exposed outer parts and the protected inner parts. If weathering has gone on long enough, the outer parts will be discolored (due to chemical change) and much softer. The outer layer of "rotten" sandstone may often be crumbled off with the fingers. The inner part of the specimens will be unstained and much harder than the outer parts. Softer rocks, such as shale, weather much faster than harder rocks.

EXPERIMENT 18. HOW DO EXPANSION AND CONTRACTION BREAK ROCKS? (P. 138). Apparatus and materials needed are as follows:

Strip of window glass about three by six inches
Piece of glass tubing
Bunsen burner or other heat source

The glass breaks in each case. Glass conducts heat poorly; thus part of glass in hottest part of flame heats and expands. Cooler parts of glass do not expand so much. This unequal expansion causes glass to break. Same principle may be applied to rocks raised to high temperatures by direct sunshine.

EXPERIMENT 19. HOW DOES WATER ACT WHEN IT FREEZES? (P. 139). Apparatus and materials needed are as follows:

Glass bottle which can be stoppered tightly

Access to a refrigerator or supply of crushed ice and salt if weather is not cold enough to freeze water in bottle when bottle is placed out-of-doors.

The experiment may be done by a pupil committee and results reported to the class. A screw-top bottle is likely to give the best results because such a stopper cannot be forced out. Call attention to the fact that water does not follow the usual laws of expansion and contraction, since pupils will previously have had experiences which show that materials expand when they are heated and contract when they are cooled. As it is cooled water contracts until it reaches 39° F., when it begins to expand. Make application of the results of the experiment to water freezing in cracks in rocks and causing them to break.

SELF-TESTING EXERCISES (P. 141). 1. If outside is different from inside, we know that outside has been changed by chemical weathering.

2. By uneven expansion and contraction of different parts of rock and by water in the cracks in the rock. When this water freezes, it expands and cracks the rock still more.

3. (a) By sending their roots down into cracks of rock. As roots grow, they force rocks apart and finally cause them to crack and break.

b) Chemicals given off from roots of some plants and from decaying of some plants help dissolve away surface of some kinds of rock.

c) Dead plant materials decay and are added to soil. In this way not only amount of soil is increased but also fertility.

PROBLEMS TO SOLVE (P. 141). 1. Outside may be soft and crumbly. May be cracked by various external agents. May have a different color. May be rounded and smooth instead of sharp and angular.

2. By supplying oxygen for oxidation. By supplying carbon dioxide that forms an acid which helps dissolve some rock substances. By carrying sand that acts as an abrasive to wear away rock. By dropping

rain water to wash away covering, cause chemical changes and freeze in cracks. By carrying away heat to cool and crack rocks.

3. When we analyze soil, we find that it is made up of same materials that make up rocks in region.

4. Ideas that should be included: (a) Without soil no land plants could grow except few that grow on rocks, i.e., some lichens and a few air plants. (*b*) Without plants there could be no animals, since plants are ultimate source of food for all animals. (c) There would be no coal deposits for use as fuel, since these are all remains of plant life of millions of years ago. (*d*) Probably no oil deposits, since these are thought to be remains of plant and animal life of millions of years ago.

5. Characteristics of quartz, feldspar, and mica.

MINERAL	COMPOSITION	CHARACTERISTICS
Quartz	Silicon dioxide	Crystal clear, colorless when pure Often with some shade of yellow, red, brown, green, blue, or black due to some impurity When perfect, 6-sided prisms Hard
Feldspar	Silicate of aluminum + sodium, calcium, potassium, or barium	Occurs in igneous or metamorphic rock Hard Breaks into 3 cleavage planes White, pink, yellow, red, dark greenish brown
Mica	Silicon + aluminum, iron, magnesium, or hydrogen	Splits perfectly into very thin sheets Sheets tough and elastic Not very hard In granite or other metamorphic rock Silvery white, grey, pink, green, black

6. Several kinds of rock may be found in the locality. Also, varying amounts of humus depending on plant life. Water may sort clay and sand and deposit them separately.

7. Adds humus to soil and helps restore many necessary materials that have been taken from soil.

PROBLEM 2: HOW ARE MATERIALS CARRIED FROM PLACE TO PLACE? (P. 142)

In the preceding problem the pupils learned how rocks are broken up. The agencies for transporting materials, the conditions under which deposition occurs, and the resulting sedimentary rocks and surface features that are formed, are the topics which logically follow Problem 1. Undoubtedly, the pupils will already be familiar with many of the surface features (deltas, islands, flood plains, etc.) which are treated here. However, the teacher will note from the way in which the text is written that the emphasis is to be put upon the processes which cause these land forms rather than upon the forms themselves.

The following are the main ideas to be emphasized in this problem:

1. Moving water carries materials.

a) Materials carried by water are moved from higher to lower places.

b) The amount of material that water can carry depends upon how fast the water is moving.

c) Materials carried by water are sorted as to size when they are deposited.

2. Streams form valleys by erosion.

3. Caves are formed in limestone regions by water containing carbon dioxide in solution seeping down and dissolving the calcium carbonate of which limestone is made.

4. Flood plains are covered with deposits of fine soils when streams overflow their banks and slow down in their rate of flow.

5. Deltas are formed where streams enter still bodies of water.

6. Accumulation of minerals in large bodies of water which have no outlets makes the water of these bodies salty.

7. Deposits of dissolved minerals form special kinds of deposits in caves and about hot springs of water.

8. In dry regions, wind-carried materials are deposited in sand dunes and other formations.

9. Glacial drift is left at the ends of glaciers in moraines.

10. Glacial valleys and lakes are carved by moving glacial ice.

11. Deposits of glacial material show that a great ice sheet once covered much of the northern part of North America.

12. Masses of eroded material may harden into various kinds of sedimentary or stratified rock.

13. Limestone is formed at the bottoms of large bodies of water from chemicals dissolved in water and from the chemicals in the shells of water animals.

14. Remains of plant and animal bodies are often found in sedimentary rocks and are known as fossils.

15. Heat and pressure can change sedimentary rocks, such as shale and limestone, into metamorphic rocks, such as slate and marble.

SELF-TESTING EXERCISES (P. 147). 1. (a) Materials moved by water are carried to lower places by the force of gravity.

b) Amount of material water can carry depends on how fast water is moving. When water is moving fast, it can carry more than when it is moving slowly.

c) Water sorts materials it carries.

2. In suspension and in solution. Mud and sand are carried in suspension. They settle out when water slows down or stops. Many minerals are dissolved in water. Their particles are too small to be seen and will not settle out even when water stops.

3. Ground water contains carbon dioxide from decay of plants and animals in soil. Carbon dioxide changes calcium carbonate of limestone to calcium bicarbonate. Calcium bicarbonate dissolves fairly easily in water.

PROBLEMS TO SOLVE (P. 147). 2. Rapidly moving water (just after it has dropped over the fall) carries more material than when it is moving more slowly. Thus the material is moved away from the base of waterfalls and dropped farther away where it slows down.

SELF-TESTING EXERCISES (P. 152). 1. By action of water in streams that flow through them.

2. Young valley is narrow and V-shaped with steep sides. Mature valley is U-shaped and has a wider floor than a young valley. An old valley is wider than a mature valley. It has a broader floor, and the sides are more gently sloping.

3. It is carrying off the fertile topsoil and making many acres of land useless for agriculture.

4. Wind drives water in waves against shore. Soil is carried from shore, and sand and gravel are dropped to form beaches. Along rocky shores waves loosen rocks that are pounded against shore and against each other. This grinds up rock and wears away shore.

5. Caves are formed in regions where rock is limestone. Soil water carrying dissolved carbon dioxide finds its way down into small openings in rock and begins to dissolve it. As this continues for a long time, the hole gets larger and larger, and finally a cave is formed.

PROBLEMS TO SOLVE (P. 153). 1. *At the head of a young valley:* (a) Stream running rapidly. (b) Very narrow valley—V-shaped. (c) Steep sides. (d) Material not deposited but carried by swift-moving water. (e) Water course mostly straight. (f) Water clear.

In more mature parts of valley: (a) Wider floor of valley. (b) Valley U-shaped—sides more gentle. (c) Water running a little more slowly and stream wider. (d) Some materials dropped by more slowly moving water. (e) Water course begins to go from side to side.

As valley gets older and finally is classed as an old valley: (a) Water flowing very slowly. (b) Materials being deposited. (c) River meandering, or going from side to side of valley. (d) Broad floor of valley. (e) Very gentle slopes to side of valley. (f) Water probably clouded with suspended materials.

4. Some excellent bulletins on soil erosion control may be obtained from the U. S. Department of Agriculture.

SELF-TESTING EXERCISES (P. 158). 1. (a) Flood plain is formed when a river overflows onto flat regions along its sides. Water deposits soil and humus that were in it and thus builds up a rich plain from soils carried down from farther upstream.

b) At some point in river something acts as an obstruction. Water is thus slowed down, and mud and other materials are deposited. When river is low at some time, plants have a chance to grow on mud deposit. Their roots hold soil, and more soil is deposited against this increasing collection of materials, forming an island.

c) A delta is formed when water of a river is stopped by ocean. Mud and silt carried by river then settle out. Gradually, as more and more material is deposited, land is formed. This formation is known as a delta.

2. A lime formation found hanging from the roofs of caves. Escape of carbon dioxide from water containing dissolved lime forms deposit of solid lime.

3. Hot water dissolves many minerals down in earth. When water reaches surface of earth, it cools and part of it evaporates. These changes cause most of the dissolved minerals to change back to solid form.

4. From minerals brought in solution by rivers and streams emptying into it. No outlet for ocean water, and as it evaporates, minerals remain in water that is left. More and more minerals are brought down by rivers, and the solution becomes stronger.

5. Keep river in narrower channel than it would have if not restrained. Narrowing of channel makes water move more swiftly. As the water moves swiftly, material is carried down stream instead of being deposited. In addition to this, the more swiftly moving stream helps to dig its own channel deeper.

PROBLEMS TO SOLVE (P. 159). 1. May include any flood experiences of students; deposits of soil, etc., on the sidewalk or road after a heavy rain; small flood plains to be seen at sides of any small, slowly moving stream; caves with stalactites, etc.; beaches; etc.

2. An excellent idea of how erosion occurs can be obtained by allowing water from a hose to wash down a small hillside either already present or artificially constructed.

3. In older part of valley water is running more slowly, and gravel is deposited instead of being carried forward as it would be by swiftly moving water of young valley stream.

4. When streams spread over their flood plains the greater deposit of materials is near the edge of the stream. This builds up the banks, or natural levees, until the stream may actually be held between natural levees in a channel higher than parts of its flood plain.

5. Material deposited on flood plains has been taken by erosion from the topsoil of regions further upstream. This material is rich in minerals needed by plants.

SELF-TESTING EXERCISES (P. 162). 1. (*a*) Plowing up of grass whose roots held the soil. (*b*) Dry weather for several years so that there was not enough moisture to hold soil together.

2. Wind moves sand, and when sand strikes plant or some object, a small drift is formed. This is the starting of a dune, and it gets larger as more sand collects against this drift. Movement of dune is stopped when plants can get started growing on it. Sand is held in place. As more vegetation grows dune becomes stationary.

SELF-TESTING EXERCISES (P. 167). 1. When snow in very cold or cool regions does not all melt in summer but changes into little granules of ice. Every year more of this kind of ice is added until the layer becomes very thick, and we have a glacier.

2. Glacial valley is rounded and smooth, while stream-cut valley is rough and irregular. Ice of glacier as it moves along carries rocks and boulders with it. These scrape along bottom of valley digging out bottom and sides and smoothing them as it moves.

3. Piles of materials left by a glacier. One kind is found at ends of glaciers where ice melts and drops materials it is carrying.

4. (*a*) Shape of valleys and hills. (*b*) Materials left by glacier —moraines, large boulders, etc. (*c*) Scratches and marks on rocks covered by glacier. (*d*) Glacial lakes.

5. Because glacier is much thicker at center. Weight of ice causes such great pressure at center that ice is forced to flow outward from center.

EXPERIMENT 20. WHAT ARE THE CHARACTERISTICS OF THE COMMON SEDIMENTARY ROCKS? (P. 168). Apparatus and materials needed are as follows:

Specimens of shale, sandstone, and limestone	Knife
	Piece of window pane
Magnifying glass or hand lens	Hydrochloric acid

This experiment may be handled in several ways, depending upon the available materials and the amount of time which can be devoted to it. (*1*) Have each pupil make tests upon specimens of each kind of rock as an individual laboratory exercise. (*2*) Divide the class into small groups. Have each group perform the experiment. (*3*) Lack of specimens may make necessary the doing of the experiment as a teacher demonstration, with each pupil examining the material individually as it is displayed later in some convenient place in the room.

(a) Small crystal-like grains can probably be seen in sandstone. Shale generally has the finest particles of the three kinds of specimens mentioned. Shale breaks into very thin layers or flakes. Any of these specimens may contain fossils.

(b) Shale will be scratched easily with the knife and with glass. Tiny particles of sand can be scratched from sandstone. Limestone will probably be the hardest of the three.

(c) Wet shale has the odor of moist earth.

(d) Hydrochloric acid causes limestone to bubble (give off carbon dioxide). Caution the children as to care in using acid. The experiment should be extended (if time permits) to include many kinds of rock and mineral specimens from the environment. Use simple rock and mineral identification keys to aid in building up museum displays and teaching specimen collections. Include sedimentary, igneous, and metamorphic rocks. Specimen sets for aid in identification are available from many dealers in scientific supplies.

SELF-TESTING EXERCISES (P. 171). 1. Limestone, sandstone, shale, and conglomerate (three to be named). Limestone is formed at the bottom of bodies of water mainly from the shells and skeletons of animals that take the lime from the water. First stage in formation of sandstone is depositing of sand or smallest particles of rock formed by erosion by some body of water. Later, dissolved minerals seep down through it and material is piled in great amounts on top of sand. Pressure of materials above it and cementing action of minerals make sandstone from sand. Shale is formed in same way from deposited mud. Conglomerate is formed in same way from deposited gravel.

2. Shale is sometimes turned into slate and limestone into marble.

PROBLEMS TO SOLVE (P. 171). 1. Quick-growing plants hold sand. Plants die and add humus. More and more plants grow, die, and decay until fertile soil is formed.

2. Waves erode material from one part of shore line and deposit it as sand on another part depending on direction of prevailing wind. Wind picks up dried sand from shore and blows it up into dunes.

4. In both transportation by moving ice and by moving water,

all movable material in path of ice or water is carried along. In transportation by water the material is sorted out, and larger pieces dropped out when water begins to slow down. Material transported by water is rounded and smooth, while that transported by glaciers very often is flat and scratched in a characteristic way.

In transportation by ice, material of all kinds and sizes is carried throughout the body of the ice. The material dropped is not sorted, but all kinds are found together in moraines left by glacier.

5. Removal of weathered parts exposes rock beneath it directly to air with its oxygen for oxidation and carbon dioxide for formation of carbonic acid. Also exposes rock to rain and sun.

6. Water erosion. Reasons for believing this: (a) Great amounts of soil carried down to seas in rivers, for example, the Mississippi. (*b*) Great floods of recent years. (c) Local erosional areas in any district, such as certain fields that should not be plowed, etc., roadsides that need planting, etc.

PROBLEM 3: HOW DO VOLCANOES CHANGE THE EARTH? (P. 172)

Volcanism is one of the processes that change the surface of the earth. However, the interior of the earth just underneath the surface is probably changed more by movements of molten material than the surface is. Quiet lava flows should receive stress along with spectacular volcanic eruptions because the former have played a large part in many parts of the earth in building up rich soils. A careful study of igneous rocks should be made in connection with this problem, as was done with sedimentary and metamorphic rocks in the preceding problem.

The main ideas to be stressed during the study of this problem are:

1. Scientists have evidence for believing that the interior of the earth is very hot.

2. The source of the heat of the interior of the earth is not definitely known, but scientists believe it may be due to:

a) The presence of radioactive elements in the earth.

b) The pressure of rock material near the surface on material deeper in the earth.

3. Much of the interior of the earth is believed to be a plastic solid.

4. Heated rock material beneath the earth's surface changes to liquid when the pressure above is released.

a) Melted rock forces its way in between layers of rock and hardens to form igneous rocks.

b) Melted rock sometimes flows quietly out upon the surface of the earth to form lava flows.

c) Gases mixed with melted rock material may cause eruptive volcanoes.

EXPERIMENT 21. HOW ARE CRYSTALS FORMED? (P. 174). Apparatus and materials needed are as follows:

Copper sulphate	Bunsen burner or other source of heat
Alum	
Two vessels for heating solutions	Cloth to wrap around one vessel

a) Suspending a small crystal of the same kind of material as that of the solution (known as *seeding* the solution) will cause crystallization to occur more quickly. The nail (suggested in the experiment) is to give the crystals some object to form upon. Quickly cooled materials form small crystals.

b) Large crystals form in solutions that are cooled slowly.

Extend the experiment by letting the children make crystals from other kinds of substances: sugar, salts, Epsom salts, etc. Old-fashioned sugar candy shows large crystals when made by the directions of part a of the experiment. Use a plain string with no nail attached. Observe characteristic crystal shapes with a hand lens. Observe crystals in igneous rocks.

SELF-TESTING EXERCISES (P. 178). 2. (*a*) In deep mines and wells temperature rises a degree for each 50 feet of depth. (*b*) Melted rocks come up out of volcanoes. (*c*) Steam and hot gases come up through openings in earth.

Inside of earth may have gotten its heat as follows: (*a*) By great pressure of outer layers of earth on inside layers. (*b*) Heat might have been left from time when earth was formed. (*c*) Perhaps heat is caused by radioactive elements in earth.

3. Masses of rock melt deep in earth's interior and start to work toward surface. Rock does not reach surface but pushes its way in between layers of solid rock and starts to cool and harden. As it cools, crystals are formed, and rock is a crystallized type. This is known as igneous rock.

4. By size of crystals in rock. If rock cooled slowly, crystals are larger than if it cooled rapidly.

5. Explosions in earth blow melted rock into small pieces of different sizes and shoot it into air.

6. No. Some come from cracks that opened in rocks and allowed melted rock to pour out.

PROBLEMS TO SOLVE (P. 178). 1. Sedimentary rock is formed by depositing of layers of materials that give the rock its characteristic structure. Igneous rock, however, is formed by cooling and crystallization of melted rock.

2. It is formed and comes from interior of earth where no plants or animals live. Furthermore, any fossils present would be melted and unite with the other rocks.

PROBLEM 4: HOW ARE MOUNTAINS FORMED? (P. 179)

Scientists are not certain what is responsible for mountain-forming forces. Known factors are (1) folding due to lateral pressure upon rock layers, and (2) the tendency of great sectors of the earth to maintain their balance over long periods of time (the theory of *isostasy*). Whatever the causes of mountain formation are, the wise teacher will recognize the necessity of presenting something of the nature of how highlands are renewed because these processes must necessarily accompany processes which wear down the earth's surface.

The following are the main ideas to be developed during the study of this problem:

1. Scientific evidence shows that parts of the earth's surface are raised and lowered over long periods of time.

2. Great sectors of the earth tend to keep in balance over long periods of time. It is believed that:

a) Heavier material sinks toward the center of the earth.
b) Sinking of heavier material pushes up lighter material.

3. Rocks are often folded and broken by changes within the earth. These changes are believed to produce mountains.

4. Earthquakes result when rocks crack and slip past each other, producing vibrations.

SELF-TESTING EXERCISES (P. 185). 1. (*a*) Valleys of rivers such as St. Lawrence and Hudson run out into ocean beneath water. Since river could not have cut valleys under ocean, land must have sunk. (*b*) Beaches formed high above present ocean and showing remains of sea animals indicate that land of that region must once have been lower. (*c*) Layers of sedimentary rock above water at present show that region must once have been under water, since sedimentary rock is formed by depositing of material by water.

2. (*a*) Folding of rocks. (*b*) Bending of rocks. (*c*) Faults and earthquakes. (*d*) Mountains are formed.

5. (*a*) Formation of faults. (*b*) Volcanic activity.

PROBLEMS TO SOLVE (P. 185). 1. Volcanoes have a definite cone-shaped structure and are made up of deposits of volcanic cinders, ash, and lava. An ordinary mountain peak is not always cone-shaped, may have been formed in several ways, and may be made of other kinds of rock than lava, etc.

2. (*a*) Formed under water by deposition of materials dissolved in water and of bony parts and secretions of plants and animals, and by the pressure of successive layers of this material that finally changes it to rock. (*b*) Movements of earth, or diastrophism, cause rock to be raised high above sea level as mountains are formed. (*c*) Erosion occurs, wearing away rocky materials around limestone and leaving it exposed high on mountain.

LOOKING BACK AT UNIT 3. (P. 186). 3. A *block mountain* is formed by elevation and tilting of land between two faults.

A *flood plain* is the level area along the banks of a river that is normally covered with water during floods.

Ground water is rain or melted snow that soaks into the soil and remains there.

Igneous rock is rock formed by the cooling of melted rock.

A *plateau* is a great area of level land higher than surroundings.

A *moraine* is a hill or ridge of unsorted clay, stones, rock, and gravel transported and left by a glacier.

Erosion is the wearing away of rock and soil by wind, water, and chemical action.

A *fault* is a break in the bed rock of the earth where one part of the rock slips past another part.

Loam is soil that contains about fifty per cent of sand mixed with almost equal parts of clay and humus.

Quartz is a mineral made of one part silicon and two parts oxygen.

A *delta* is land formed when the flow of water is checked at the mouth of a river and sand and mud settle out of the water.

Humus is the part of the soil made from decayed and decaying plant and animal material.

A *stalagmite* is a deposit built up when water containing dissolved lime drips onto the floor of a cave.

Diastrophism means changes in the position of rocks and movements of the earth's surface.

Sediment is material that is being carried by water.

The chemical changes that destroy rock by the action of air, rain, and sun are called *weathering*.

ADDITIONAL EXERCISES (P. 186). 1. May include making stone walls, houses, roads, monuments, etc.

2. Formed where glaciers extend down to sea. In warm weather the end breaks off and floats away in ocean in form of iceberg.

3. When a stream flows over a bed having rocks of different degrees of softness and hardness. If hard rock is farther upstream than soft rock, channel below is worn away faster than that above, and a difference in level results that makes water fall from upper level to lower.

4. Crescent-shaped lake formed on flood plain by a stream that wanders or meanders over plain. As stream meanders, it may form large loops in course of river. Eventually if stream cuts off neck of land at base of loop and no longer follows this channel, old channel is left as a crescent-shaped lake known as an oxbow lake.

5. Terminal, lateral, and ground moraines. Terminal moraine is formed by material deposited by melting of ice at end of glacier. If advance of glacier equals amount lost by melting, material is deposited in one spot as a terminal moraine. Height of moraine depends on how long end of glacier was stationary. If glacier eventually recedes and end is moved back, material of terminal moraine remains as a ridge or hill.

Lateral moraine is formed when material is dropped from melting ice at sides of glacier that goes through a valley. As glacier moves through valley, debris accumulates at its edges. When glacier melts, this material is dropped as ridge along sides of valley.

Ground moraine is formed by material dropped beneath advancing ice of a glacier and left in an irregular sheet as glacier melts.

6. Sea water contains 3.44% salt. A gallon of water is 16 cups. 3.44% of 16 is .55 cups, or, roughly, a half cup of salt.

7. Yes.

8. By action of large glaciers that passed over that part of the country several times and dug out surface of earth as they moved.

14. Most famous petrified forest is in Apache County, Arizona, and is now known as the Petrified Forest National Monument. There are several others, however: one in Yellowstone National Park, one recently found in Montana outside the park, and one in the Black Hills of South Dakota. Trees became petrified when forests were covered with water containing silica in solution. Water went into the wood, and silica was deposited in cells. Wood eventually decayed, but since material in cells had been replaced molecule by molecule with silica, cell structure of tree remained and tree trunk retained its shape.

15. We believe that rocks are being formed today because we think conditions in bottoms of oceans and deep in some parts of earth are similar to those under which present stratified rocks were formed. Plants and animals are today making same type of deposits in bottoms of bodies of water that have formed present bodies of limestone. Plants and animals are sometimes found in process of petrification. Gravel and sand deposits are found partially cemented together into stone.

16. No. Only living things grow in the true sense of the word "grow," although crystals that add material to themselves and increase in size are said to be "growing." Softness of rock exterior caused by chemical action.

BULLETIN FOR UNIT 3

United States Department of Agriculture

Misc. Publication No. 321. *To Hold This Soil.* 45c

VISUAL MATERIAL FOR UNIT 3

MOTION PICTURES

Encyclopaedia Britannica Films

- "The Formation of Soil"
- "Volcanoes"
- "The Work of Rivers"
- "Ground Water"
- "The Work of the Atmosphere"
- "The Work of Running Water"
- "Limestone and Marble"
- "Sand and Clay"
- "Mountain Building"
- "Volcanoes in Action"
- "The Earth's Rocky Crust"
- "The Wearing Away of the Land"
- "Geological Work of Ice"

Society for Visual Education

- "Study of a Mountain Glacier"
- "Volcanoes and Geysers"

FILMSTRIPS

Society for Visual Education

- "Geology of Caves"
- "Icebergs and Glaciers"
- "Action of Running Water"
- "Decay through Atmospheric Action"
- "Wind and Mechanical Action"
- "Weathering and Wind Deposits"

UNIT 4

Why Do Some Things Rise and Others Sink in Fluids?

FUNCTION AND SCOPE OF UNIT 4. In understanding our environment those generalizations are most useful which enable the mind to grasp under a single point of view the greatest number of separate phenomena. The environment presents so many different occurrences and details that we can grasp the significance of relatively few of them unless they can be seen as instances of some principle or general process that we already understand. This unit brings under a single great generalization (Archimedes' Principle) all cases of floating and sinking in liquids and gases, apparent lessening of weight in liquids and gases, and all cases of circulation due to differences of density (convection currents). Refer to the graph on page 122.

Of very great help in grasping the principle of this unit are the ideas of Unit 2, "How Is the Force of Gravity Useful to Us?" Especially important are (1) the concept of density (pages 85-86), (2) the idea that fluids exert pressure in all directions (page 89), (3) the concept of gravity as the cause of pressure in fluids (pages 88-90, 100-103), and (4) an understanding of the increase of pressure with depth (pages 90-93, 104-105).

Understanding of the principle of this unit is essential to a satisfactory understanding of Unit 6: "How Do We Control Heat?" and of Unit 7: "What Makes the Weather Change?" It will also be extremely useful in Unit 3 of *Book 3:* "How Are Plants and Animals Fitted to the Conditions Around Them?" (Flotation in Water.)

In cases of pupils who already have the concept of flotation the unit should serve to broaden their knowledge of its cause and of examples. Then they should be able to do many of the Problems and Additional Exercises or to read in physics books about the ways in which Archimedes' Principle is applied.

INTRODUCTORY EXERCISES (P. 190). 1. Lists of materials will vary. Materials that are less dense ("lighter") than water float in it, while those that are more dense ("heavier") sink in water.

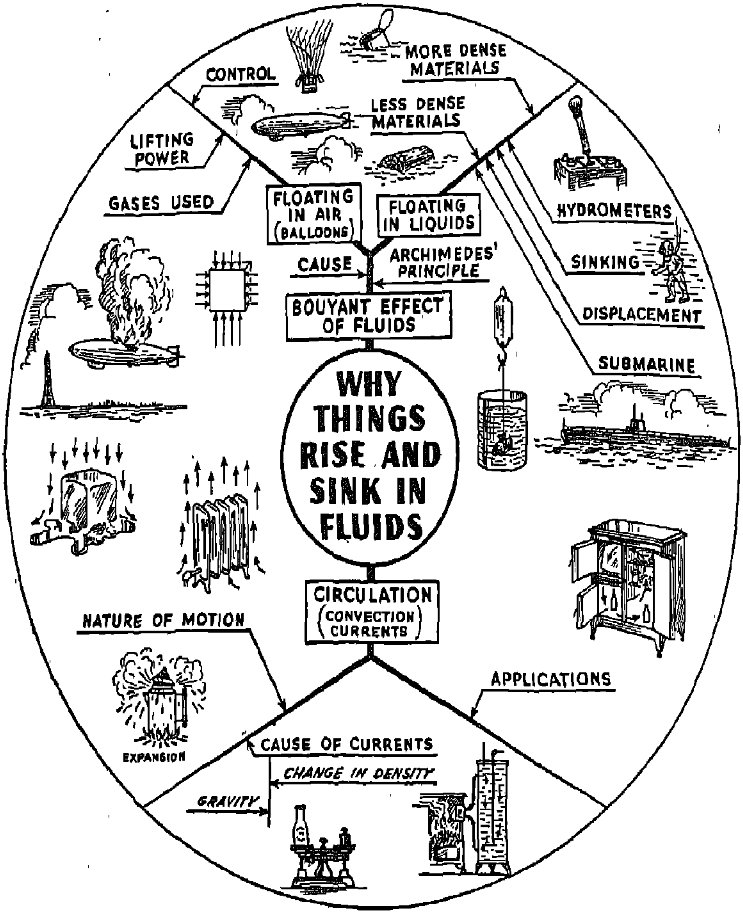

FIG. 7. GRAPH OF THE SUBJECT MATTER OF UNIT 4

2. A piece of steel weighs much more than volume of water it displaces and therefore sinks. But boats of steel are made hollow in such a way that they displace more than their own weight of water.

3. Seems to become less. Objects such as heavy stones under water seem "lighter" than in air.

4. Submerges by filling certain tanks with water, thus making submarine heavier. To rise compressed air is forced into these tanks, driving water out and making submarine lighter.

5. Pushed up by air. Balloon filled with hydrogen displaces large volume of air and is filled with a material less dense (lighter) than air. Air thus pushes up on balloon harder than gravity pulls hydrogen and balloon downward.

6. Moves up from stove because warm air expands and becomes less dense (lighter). Cold air pushes it up because it is more dense (heavier) than warm air.

*7. (a) *Expand* means to grow larger; *contract*, to grow smaller.

b) Substances expand when they grow warmer. Water or other liquids expand when heated so that they run over or escape from their container. Mercury in thermometer is an example of expansion and contraction in accordance with temperature.

8. Density becomes greater when a material contracts. Since molecules are closer together when material contracts, more molecules are contained within a given space; this gives material greater density.

9. When water is heated, part that gets warm first expands and becomes lighter. Cold water pushes lighter warm water up, comes in to take its place, and is in turn heated. Part in center nearest flame would become heated first, and cold water would come in from sides.

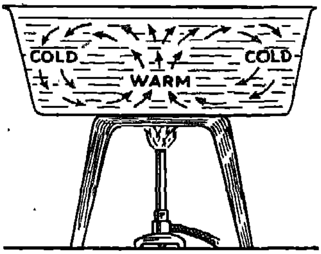

FIG. 8

Looking Ahead to Unit 4 (p. 191). The incidents described in this section show clearly how interest in the problem of the unit may be stimulated. It is suggested that teachers use a number of oral questions in beginning this introduction to the unit. Pupils will be interested in discussing the questions and may be led to ask many questions of their own about things that go upward seemingly of their own accord. The teacher may then briefly summarize the problem that is to be solved—what the class is to find out—or have the class read the introduction as it is given in the book. The main idea is to get pupils to thinking about the cases where things go up instead of down and wondering why.

PROBLEM 1: WHY DO SOME OBJECTS FLOAT AND OTHERS SINK? (P. 193)

This problem is solved when pupils are able to visualize a fluid as exerting an upward force on any object immersed in it and the weight of the object as being a downward force exerted against the lift. They can then readily learn to predict which force will be the "winner." The main ideas of the problem are:

1. An object placed in water (or any other liquid) is pushed upward by a force equal to the weight of water (or other liquid) displaced by the object. This lifting effect is due to the difference between the pressure on the top and on the bottom.
2. When the density of the object is greater than that of the liquid, the object sinks.
3. When the average density of the object is less than that of the liquid, the object is lifted to the surface and floats.
4. The density of a liquid can be measured by finding how much of a floating object projects above the liquid.
5. In gases the principles of flotation apply just as they do in liquids, but the weight of gas ("air") displaced by a balloon becomes less as it rises; thus it floats within the atmosphere instead of rising all the way to the top.

EXPERIMENT 22. HOW DOES THE WEIGHT OF A STONE IN AIR COMPARE WITH ITS WEIGHT IN WATER? (P. 194). Apparatus and materials needed are:

Jar of water—Figure 152 (or cylinder for Experiment 23)

Spring balance marked in grams

Stone that will go into this graduated cylinder

Thread or string 18 inches long

Most pupils will not have observed that objects submerged in water get lighter. Every one should be allowed actually to experience the change in apparent weight by reading the balance with the stone in and out of the water. The weight recorded for the stone in air should be that of the *dry* stone. The amount of the apparent loss of weight is not important in this experiment but should be recorded for use in Experiment 23. It will be well to use two or three different stones and to emphasize the importance of several trials for accurate results.

EXPERIMENT 23. HOW DOES THE WEIGHT LOST BY A STONE IN WATER COMPARE WITH THE WEIGHT OF THE WATER IT DISPLACES? (P. 194). Apparatus and materials needed are:

Stone and string used in Experiment 22
Water
Large glass cylinder graduated in cubic centimeters (Figure 153)

Give some attention to the neat and helpful arrangement of the data in this experiment. It should be so arranged that the comparisons called for are easily made by the pupils. The following form will be satisfactory and provides for the use of three stone or metal objects of different sizes.

Results of Experiment 23

	No. 1	*No. 2*	*No. 3*
(1) Weight of object in air	...g.	...g.	...g.
(2) Apparent weight in water	...g.	...g.	...g.
(3) Apparent loss of weight in water	...g.	...g.	...g.
(4) Water displaced	..cc...g.	..cc...g.	..cc...g.
(5) Differences between (3) and (4), if any	...g.	...g.	...g.

The differences obtained should be very close to zero.

SELF-TESTING EXERCISES (P. 197). 1. Because it was pushed upward by force of water equal to weight of water displaced by soap.

Since soap weighed less than amount of water displaced, it was pushed to top instead of sinking. (Note: Soap is really more dense than water. Some kinds of soap are made less dense by beating air into them. These kinds float.)

2. Apparent loss would be 124.8 lb., or weight of the 2 cu. ft. of water displaced. True because water is pushing up on iron with force equal to weight of water displaced.

3. Archimedes' Principle states that any object placed in a fluid is buoyed up by force equal to weight of fluid it displaces. Examples of how this principle works will vary. They may well include the apparent loss of weight of any objects in liquid but should preferably be those completely immersed. Pupils should give real examples of their own or from the text rather than fictitious ones. Possibilities are: submarine (apparent weight when immersed is zero), Archimedes' crown, stones used in Experiments 22 and 23, etc.

PROBLEMS TO SOLVE (P. 198). 1. Not true. Ship is buoyed up by force equal to weight of water displaced. If ship were lighter than this force, it would not sink at all, but fact that it sinks shows that force pulling down on it is greater than force pushing up; therefore it will be pulled all way to bottom. This occurs because water is so nearly incompressible that its density (and lifting force) is very nearly the same at top and bottom.

2. Because in water the stone was buoyed up by force equal to weight of water displaced by stone; therefore stone seemed to weigh less by this much. Out of water full force of gravity was acting on stone making it too heavy for boys to lift.

EXPERIMENT 24. HOW CAN A PIECE OF DENSE METAL BE MADE TO FLOAT IN WATER? (P. 198). Apparatus and materials needed are:

- Two pieces of tinfoil or aluminum foil about three inches square
- Pan of water
- Block of wood about two inches square

The box-shaped piece of foil floats, while the piece rolled into a ball sinks. The exact explanation need not be required until the pupils have studied the explanation given later. If they can explain, they may, of course, be allowed to do so.

Experiment 25. How Does the Weight of a Floating Object Compare with the Weight of the Water it Displaces? (p. 198). Apparatus and materials needed are:

- Test tube
- 100 cc. graduated cylinder (Figure 155)
- Dry sand
- Water
- Metric weights (optional)

The results of this experiment should be systematically recorded. A form like the one below is suggested.

	Trial 1	*Trial 2*	*Trial 3*
(1) Weight of tube and contents	...g.	...g.	...g.
(2) Water displaced	..cc...g.	..cc...g.	..cc...g.
(3) Differences between (1) and (2), if any	...g.	...g.	...g.

Self-Testing Exercises (p. 204). 1. Its average density is less than that of water.

2. Steel ships are hollow; therefore they displace a much larger weight of water than the material in them weighs. For this reason a ship floats.

3. Will float better even when it contains water because it will displace more water and weigh less per cubic foot than without hollow compartments. Force pushing up on boat will be increased; thus boat will be kept afloat better.

4. Density of liquid. An instrument consisting of small glass tube with weight in end so that it will float upright in liquid. Density of liquid is seen in extent to which hydrometer must sink to displace its own weight of liquid. The denser the liquid, the less it must sink. Relative densities are read from a scale inside the glass hydrometer tube.

Figure 163 (p. 205). The tanks when full of water were denser on the average than the water around them. Thus gravity pulled them to the bottom. After they were attached to the submarine and the water was forced out of them by air, they were much less dense than the surrounding water. The water, pulled downward by gravity, forced the tanks upward to the top, and they carried the submarine with them.

PROBLEMS TO SOLVE (P. 205). 1. Iron and silver would float. Gold and platinum would sink.

2. Ice floats in water. Density of ice is less than that of water.

3. (a) In being constructed so that it can be made to weigh just as much as, or a little more than, the volume of water it displaces so that it will sink.

b) To raise a submarine, water admitted to certain tanks to make the boat sink is driven out by compressed air. Boat then becomes lighter than water it displaces and rises to surface. This works because of fact stated in Archimedes' Principle that an object in liquid is buoyed up by force equal to weight of water displaced. If weight is less than that of water, boat is pushed up by force of water beneath it.

4. (a) Ton of water.

b) 32.05 cu. ft. (2000 ÷ 62.4)

5. 62 lb. of water. (135 − 73) 1 cu. ft. or slightly less than 1.

6. 62.4 lb. per cu. ft. Volume of body will be its weight divided by 62.4 lb., the weight of 1 cu. ft. of water.

7. Fill two graduated cylinders to same height, one with liquid to be tested and other with water. Put sand-filled test-tube into each and compare amounts of liquids displaced when tube sinks to point where it will float. If less is displaced in the new liquid than in water, then the new liquid is denser than water. If more is displaced, then it is less dense, since it must displace more liquid before its weight is equal to that of tube and sand.

A still simpler method is to float the test tube in water and mark the depth to which it sinks. Then float the tube in the other liquid. If it sinks farther, the second liquid is less dense, and vice versa.

8. Making a toy submarine (Cartesian diver). Pressure on water forces some of it into diver and compresses air inside. As a result, the bottle and contents become heavier and sink. Releasing pressure allows compressed air to force some water out of small bottle, and it rises.

SELF-TESTING EXERCISES (P. 210). 1. (a) Against bottom. (*b*) Air-pressure increases as you go down through atmosphere. (c) It supports balloon and its load.

2. Hydrogen is lighter than air; therefore balloons will be pushed up by air if filled with hydrogen.

3. It contained many large bags filled with a gas lighter than air. Amount of air displaced by bags weighed much more than weight of hydrogen in bags plus cargo and passengers. Therefore air pushed up on bags and caused them to lift balloon and its load against gravity.

4. Less than that of air.

5. Density of the air and average density of balloon. The higher the balloon goes, the less dense the air around it becomes. When balloon rises to point where density of air is equal to average density of balloon, it stops rising. If balloon is lightened, it will rise again until it reaches height where air is less dense again and just equal to average density of balloon. Balloonist controls rising or sinking by throwing out something (ballast) to make balloon lighter, or allowing some of gas to escape from balloon bag to make it smaller and displace less air.

PROBLEMS TO SOLVE (P. 210). 1. (Balance and sugar are both inside the jar.) Sugar seems to gain weight. When immersed in air, it is buoyed up by surrounding air just as an object is in water, but to a lesser extent. When the air is pumped out, it ceases to exert a lift on the sugar. (Note: The lifting effect of air on the brass weights of a lever balance may be mentioned by thoughtful pupils. This effect will tend to offset the buoyant effect on the sugar but will not be so great as on the sugar because the weights will take up less space.)

2. (a) In vacuum, because there was no air pushing up on it, and force of gravity had nothing subtracted from it.

b) Yes. No air was pressing down or pushing up on can, and gravity was only force acting on it.

c) Weighed less than when full of hydrogen and in vacuum. Hydrogen has weight. When hydrogen was removed, can weighed less.

3. Jar contained gas heavier than air. Shown by fact that the gas sank to bottom of jar and by fact that bubbles filled with air were buoyed up by the gas.

4. (In the first and second printings of *Science Problems, Book 2* the weight of the balloon is given as 900 pounds, and in all subsequent printings as 200 pounds. Calculations for both weights are given on the next page.)

Weight of hydrogen = 12 × 5.6 = 67.2 lb.
Weight of air displaced = 87.9 × 12 = 1054.8.
Weight of balloon = 200 lb. or 900 lb.
Lifting power of balloon = 1054.8 — 267.2 = 787.6 lb.
1054.8 — 967.2 = 87.6 lb.

Simpler method: Lifting effect of air on 1000 cu. ft. of hydrogen is 82.3 pounds.

Total lifting effect of gas in balloon = 12 × 82.3 = 987.6
Weight of balloon = 200 lb. or 900 lb.
Net lifting power = 987.6 — 200 = 787.6 lb.
987.6 — 900 = 87.6 lb.

PROBLEM 2: HOW DOES GRAVITY CAUSE WATER AND AIR TO CIRCULATE? (P. 211)

Convection currents are one of the most commonly observed phenomena of nature. They are really just a special example of the operation of Archimedes' Principle. By studying them as such, pupils do not need to learn a new principle but only a new application of one which they have already grasped. The main ideas developed in solving the problem are:

1. When a fluid is warmed in one place, the warmed part ordinarily moves up; when cooled, the cooled part moves downward. If the difference of temperature is maintained, a constant current of fluid is created.
2. Heating decreases the density of fluids by causing them to expand; cooling increases the density by causing contraction.
3. The circulation caused by differences of temperature is due to gravity pulling downward with more force on the cooler, and therefore more dense fluid, than it pulls down on the warmer, and therefore less dense fluid, beside it. The greater buoyant force exerted by the denser part lifts the less dense part.

EXPERIMENT 26. HOW DOES WARM WATER BEHAVE IN COLD WATER? (P. 211). Apparatus and materials needed are:

8-ounce wide-mouthed bottle
2-holed stopper with glass tubes for bottle (Figure 167)
Hot water to fill bottle
Large glass jar of cold water (a metal pail may be used but results are hard to see)
Ink or other coloring material

This experiment is best done as a demonstration by a committee of pupils or by the teacher.

When performed as directed, there should be a constant flow of cool water into the bottom of the bottle and of warm water out and to the top until all the warm has been pushed out of the bottle. One must be sure the cool water reaches above the top of the projecting tube and that no air bubbles are allowed to remain in either tube to interfere with the flow. A light background makes the movements of the water show more clearly.

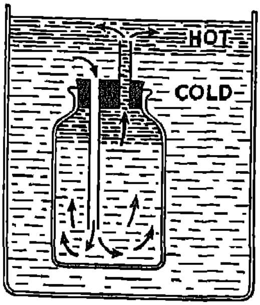

FIG. 9

In this and the following experiments (27, 28, 29) pupils *should not be asked to explain the currents they notice.* Premature explanations fix incorrect impressions more firmly in mind. The purpose here is to provide basic experiences for pupils who have not had them before and, by striking demonstrations, to bring such experiences into the center of attention. The second sub-problem then brings out the reason for the air and water currents.

EXPERIMENT 27. HOW DOES COLD WATER BEHAVE IN WARM WATER? (P. 212). Apparatus and materials needed are as follows: Same as for Experiment 26 except that the larger vessel is filled with warm or hot water. A wire handle may be provided to hold the bottle in the jar.

This experiment should be demonstrated by a committee of pupils or by the teacher. Again it is important to remove from the tubes any air bubbles that may interfere with the movement of the water. In this case the cool water will pour out into the bottom of the jar, and the warm water will enter the bottle as shown in Figure 10.

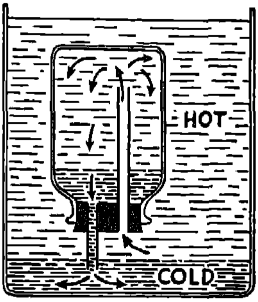

FIG. 10

EXPERIMENT 28. WHICH WAY DO THE COLD PARTS OF AIR MOVE? (P. 212). Apparatus and materials needed are as follows: Some method of detecting gentle air currents in addition to the methods mentioned in the text. Smoke screen liquid or burning touch paper may be used. The smoke screen liquid or touch paper may be purchased from scientific supply companies. The touch paper may be made by soaking towel paper or filter paper in a "strong" solution of.salt petre (potassium nitrate) or sodium nitrate and drying it thoroughly. For use the paper is cut into strips, ignited one strip at a time and held in the air to be tested. For part *b* a lighted candle may be used.

Part a should be done as a class experiment or demonstration in the classroom. It may also be carried out at home by individual pupils. Part *b* is best done at home unless there is a refrigerator in the home economics laboratory or the school cafeteria that can be used.

In each case the air disturbance caused by persons moving, by opening doors, etc., should be allowed to die down before making the test. Then the cool air will be found to flow gently toward the floor. On a cold day a striking demonstration can be performed by bringing in from the outdoors (or from a very cold refrigerator) a covered pail or jar of cold air. By gently tilting the container the cold air can be poured out. The course of the cold air is made visible by filling it with ammonia-hydrochloric acid fumes, or smoke screen fumes before pouring it out.

EXPERIMENT 29. WHICH WAY DOES WARM AIR MOVE? (P. 212). Apparatus and materials are the same as for Experiment 28. The currents in this experiment are the exact reverse of those in Experiment 28. A metal container can be heated, filled with indicating fumes (touch-paper smoke works well), and the hot air poured upward!

EXPERIMENT 30. WHICH WEIGHS MORE, A BOTTLE FULL OF HOT WATER OR THE SAME BOTTLE FULL OF COLD WATER? (P. 213). Apparatus and materials needed are:

Balances	1 large-mouthed bottle (pt. or qt.)

Flat piece of glass to cover mouth of bottle
3 pounds of dry sand
Quart can (or a set of weights totalling about 3 pounds or 1500 grams)
Hot and cold water to fill bottle
Dry cloth

The same bottle is used for both parts of the experiment to make sure of having the same volume and weight in the two parts. If the teacher will take the trouble to match two bottles with great care and to balance them against each other when filled with hot and cold water, the results will be more striking. Experiment 31 can then be done by leaving the bottles on the balance or setting them aside covered until the class meets next.

Experiment 31. Why Is the Weight of a Bottle of Hot Water Different from That of a Bottle of Cold Water? (p. 214). *Apparatus and materials needed are:*

Pyrex flask (or tin can with small mouth) of at least one pint (500 cc.) capacity
Piece of glass for cover
Water
Source of heat

This experiment is the most important one in Problem 2. If comprehended, the pupils gain an intelligent point of view toward the cause of convection currents. If not comprehended, an essential part of the understanding is lacking. The teacher should, therefore, give great care to the performance of the experiment as a demonstration and should require that pupils write it up with care and answer the problem of the title.

The demonstration can be varied by using the bottle of Experiment 30, but the contraction of the water is not so apparent. Fill the bottle with very hot water and cover it with a glass plate so that no air bubbles are included. Then let the water cool until the next day. The main drawback to this plan is that pupils do not actually observe loss of water due to expansion.

Self-Testing Exercises (p. 215). 1. Less; expands.
2. More.
3. Less than.
4. Greater than.
5. Farther apart than.

SELF-TESTING EXERCISES (P. 218). 1. Upward; more.

2. Warm air from room is cooled as it touches cold window; therefore it becomes denser, and gravity pulls it down. More warm air is pushed up and toward window, where it is cooled and sinks.

3. The examples will, of course, vary. (a) Representative of rising warm air: (*1*) Air around a stove.

2) Cigar smoke floating in air and rising around bulb of flood lamp.

3) Smoke from cigar itself moving upward.

4) Smoke and flames of camp fire moving upward in current of air.

5) "Steam" in warm air rising above pan of hot water.

b) Examples of cold air being forced downward:

1) Air moves down along window pane.

2) When I opened refrigerator door in cold weather, I felt cool air on my feet.

3) When attic door was opened in winter, cold current flowed down stairs and into lower room.

4) By holding my hand close to floor, I could feel current of cold air from large cake of ice left on floor by iceman.

5) Air from floor flows down to furnace through cold air duct.

4. Air near radiator is being warmed. As it is warmed, it expands, becomes lighter, and is pushed up by heavier cold air that surrounds it. Cool air gets warm and is itself forced up. This goes on as long as radiator is warm enough to warm air near it.

5. So that warm air that rises to top will be cooled. As it is cooled, gravity pulls it downward, and it pushes up any warm air that may be in lower part of refrigerator. This keeps up until all warm air is cooled.

6. The half gallon of water in water front is heated. As it is heated, it expands and becomes lighter. Cold water from tank pushes this warm water up through pipe to top of storage tank. Cold water that replaces it is warmed and is pushed up by more cold water. Process continues until whole 30 gallons is heated.

7. (a) At bottom of door. Cold air is heavier than warm air; thus gravity pulls it downward.

b) As the cold air comes in, warm air is pushed up and out at top of door. This continues until all warm air below top of door is forced out of room.

8. Warm air expands and is lighter. Cool air pushes up warm air, and it stays near top of room.

PROBLEMS TO SOLVE (P. 219). 1. When fire burns, it heats air in chimney. Air expands and is lighter. Cooler air from the room pushes on this warm air, moving it up chimney. Cold air is in turn warmed and replaced by more cold air; so there is steady stream of air moving in to fire and up chimney.

2. Cold air entering at bottom will force warm air at top of window to go out window if window is open. This will insure complete change of air, as all hot air is eventually forced out of top of window.

3. Near floor. If radiator is near ceiling, air is warmed at upper part of room and is held there by cold air below it. Since cold air is heavier than warm air, it does not rise to where it can be warmed by radiator, with result that lower part of room remains cold.

4. See Figure 8 on page 123 of *Guidebook.*

5. Air in chimney is warmed to higher temperature than would otherwise be true. This makes air less dense, and cold air can push it up faster.

6. Small convection current is set up by heat from bulb. Air near bulb is warmed by heat, expands, grows lighter, and is pushed up by colder air. Thus current of air is created strong enough to turn small, lightly balanced windmill.

7. Pump it. Cold water was at bottom of ocean. Water on top of it was warm and therefore lighter in weight than the cold water. It could not push down on cold water and force it up pipe.

8. Heat from sun causes gases in balloon to expand and become lighter. Balloon is then pushed up by air around it. When balloon is under a shadow, temperature is lower and gases contract again, become more dense, and balloon sinks.

LOOKING BACK AT UNIT 4 (P. 219). 1. Archimedes' Principle states that any object placed in fluid is buoyed up or pushed upward by force equal to weight of fluid the object displaces. This means that there is a force counteracting the force of gravity on an object in a fluid that is equal to the weight of the volume of the fluid that occupied the space where the object now is.

2. Examples may be any of those used in the text as illustrations or any similar ones from the pupils' own experience.

3. A *fluid* is any substance that flows or takes the shape of its container; gases and liquids are both fluids.

The *displacement* of a floating or submerged object is the amount of fluid that is pushed aside by it—the amount that would otherwise fill the place where the object is.

A *convection current* is a current in a fluid that is started and kept going by a difference in density in the fluid caused by a difference in temperature in the fluid.

ADDITIONAL EXERCISES (P. 220). 1. Put salt in water until the water becomes dense enough to float egg.

2. Make him weigh too little. Since according to Archimedes' Principle he is being buoyed up by a force equal to weight of air he displaces, he would weigh 2½ oz. more if force of gravity were not counteracted by this amount; i.e., if there were no air around him.

3. Stone was being buoyed up in liquid by force equal to weight of water displaced by boulder. This amount subtracted from weight of boulder made it light enough for men to move under water, whereas it was too heavy to lift out of water.

4. Cup really contained mercury with thin layer of milk on top of it. Mercury is more dense than iron; so iron ball floated in it.

5. To sink dock, tanks are filled with water, and dock sinks. Ship then moves in or dock is floated under ship. Water is then pumped out of tanks, and dock and ship rise until dock has lifted ship out of water.

6. If ice were at top of tube and water boiled at bottom, the warm water would be pushed up toward top by weight of cold water. Ice would be melted, and soon all water in tube would be warm.

7. Bottom of tube containing sand is denser than top. Gravity pulls down on this part more than on top, and keeps tube erect.

8. Good eggs.

9. Denser than good eggs.

10. Weigh life preserver. Immerse it in vessel level full of water and find how many pounds of water it displaces. Subtract first weight from second to get actual number of pounds it will hold up. Actual weight of a person that could be supported by the life preserver would be much greater than the figure obtained because the person would be partly immersed in water. The best test would be to have persons of different sizes use the life preserver in water.

VISUAL MATERIAL FOR UNIT 4

Encyclopaedia Britannica Film. "Refrigeration" (Part on convection)

UNIT 5

How Do We Use Energy?

FUNCTION AND SCOPE OF UNIT 5. Men who have spent much time studying the natural world have come to the conclusion that it is composed of two fundamental parts that we can study in science, materials and energy. This concept has been of great assistance to scientists and can be of similar assistance to the average citizen when he grasps it. However, it is a concept that grows slowly and requires a background of experience.

In *Science Problems, Book 1*, pupils were introduced to the idea of matter, its physical and chemical forms, its physical and chemical changes. Through a series of units they practiced using these ideas and applied them to common phenomena. They dealt in an elementary way with several forms of energy: heat, light, and the stored energy of food and fuels. Unit 5 serves to review the earlier experiences with energy, point out its universal characteristics, its many forms and transformations. Then these ideas will be used repeatedly in the remaining units of *Book 2* and through many of the units of *Book 3*.

The following ideas from earlier units are helpful in the study of Unit 5.

Book 1

Unit 4. Heat causes changes in the size and physical state of materials.

Unit 5. Heat causes chemical changes to occur.

Unit 6. Burning of materials produces much heat and light.

Unit 8. All living organisms carry on activities.

Unit 9. (a) The activities of living things require energy.

b) Food supplies the energy used by plants and animals.

c) Light furnishes plants with the energy to make food.

Unit 10. (a) When anything is moved, energy is necessary to make it move.

b) Energy is released in our bodies by the oxidation of food.

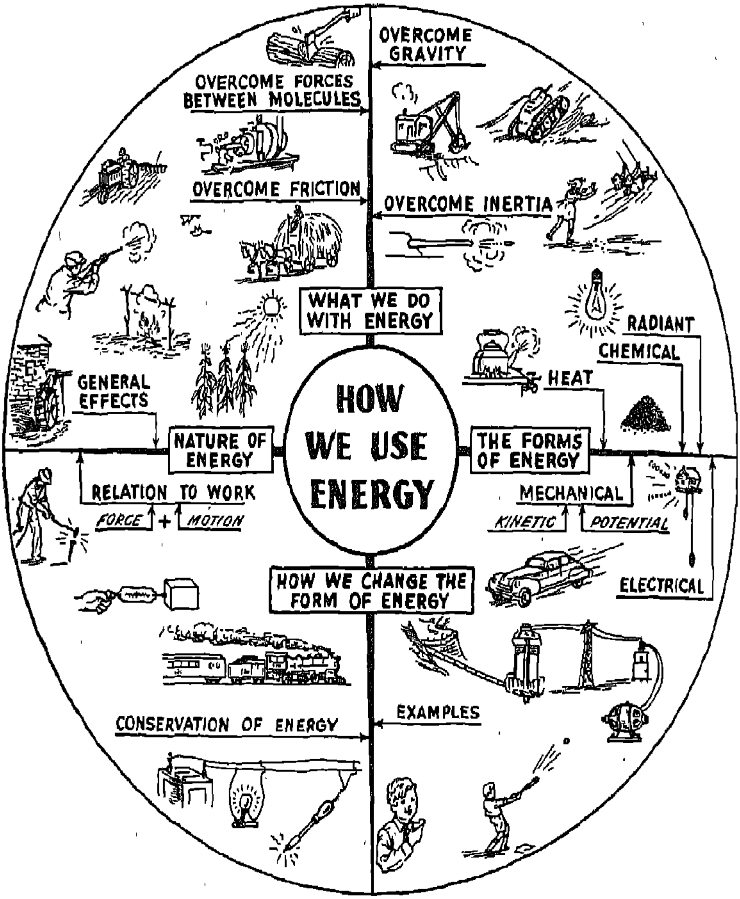

FIG. 11. GRAPH OF THE SUBJECT MATTER OF UNIT 5

c) Carbohydrates, fats, and proteins are energy-containing foods.
d) Scientists can measure in calories the amount of energy in an ounce of food.

Book 2

Unit 1. The sun contains much heat and furnishes the earth with heat and light.

Unit 2. Gravity is a force that pulls everything near the earth toward the center of the earth.

Unit 5. The ideas about energy developed in this unit will be used in many following units.

Unit 6. (a) Heat changes to radiant energy and radiant energy to heat when heat is "transferred" by radiation.
b) During changes of state, heat energy is changed into stored, or potential energy, or the reverse.

Unit 7. The changes of weather are brought about by energy and energy changes.

Unit 8. The cells of our bodies obtain heat energy and energy to do their work by transforming the chemical energy of the food they receive; this is done by oxidizing the food.

Book 3

Unit 4. Machines are used to do work (apply energy) more effectively than could otherwise be done; some of the energy is always transformed into heat by friction.

Unit 5. Electric currents are obtained by transforming other kinds of energy into the energy of electric current.

Unit 7. Light is a form of energy.

Unit 8. In using electric current, the energy of the current is transformed into other kinds of energy.

Unit 9. Many of our comforts and conveniences are due to man's turning the energy he finds in nature to his own use; energy is captured by the use of machines of various kinds.

Unit 12. The energy of coal and petroleum is rapidly being used up; we should not waste it and should use other sources as much as possible.

The length of the two preceding lists of ideas indicates the importance of Unit 5 in drawing together and systematizing ideas from previous experience for use and application in later units and in life outside school. The graph on page 138 of the *Guidebook* helps summarize these ideas.

Directions for only one formal experiment are provided in this unit. The teacher and pupils should carry out many informal experiments and find all around them, many illustrations of the ideas of this unit. The examples used in the text discussions are so common that most of them can be observed by any class. They are so similar to many other cases that, once the spirit of inquiry has been stimulated, there should be no difficulty finding a multitude of slightly different examples in every classroom and home.

INTRODUCTORY EXERCISES (P. 222). *1. The molecular theory is a theory that explains the characteristics and the behavior of matter by assuming that all matter is made up of very small particles called molecules.

*2. A magnet has energy. Energy means the capacity to do work. To do work means to move an object. Since magnets are capable of moving certain objects, they must possess energy.

3. This answer is included in the answer to Exercise 2.

4. Many different things will be and should be included in these lists. Each one should involve some change.

5. Inertia is a characteristic of all matter that makes it stand still until some outside force moves it, or that makes it keep going in a straight line until some force stops it.

6. Friction is a kind of resistance resulting from the contact of surfaces in motion, such as that between rubber-soled shoes and the floor or sidewalk; between the wheels of a wagon or automobile and the road; between a person and the slide when he is sliding down a slide; between the snow and the sled on a toboggan slide, etc.

*7. Heat is the energy of motion of molecules.

*8. Changes that heat can cause in materials:

a) Change in size—heat causes things to expand.
b) Changes in state—from solids to liquids; from liquids to gases.
c) Change in the chemical composition of materials.

9. Different kinds of energy which may be named are: (*a*) radiant energy—light energy; (*b*) electrical energy; (*c*) heat energy; (*d*) chemical energy; (*e*) mechanical energy, kinetic and potential, or stored.

*10. Different forms of matter: solids, liquids, and gases. Pupils may also list elements and compounds, or name some elements.

*11. From the food we eat. The materials in the food are combined with oxygen (oxidized or "burned") in the body; and during the change the chemical energy that was stored in the food when it was made is released and used by our bodies to grow, move, and keep warm.

12. Energy is something that makes it possible for matter to do work. Matter occupies space and has weight while energy does not (as far as our ordinary experiences go).

13. Things that energy can do to matter: (*a*) move it; (*b*) change its state; (*c*) change its chemical composition; (*d*) change its size and shape; (*e*) change its temperature.

14. Examples of one kind of energy changing into another as:
a) When a wood fire is burning, the chemical energy stored in it while plant was forming the wood is changed to heat energy.
b) When coal in the engine of a locomotive burns, the stored chemical energy is changed to heat energy. This changes to the energy of steam, and this changes to mechanical energy that moves engine.
c) The energy of a waterfall is changed to electric energy when it runs a dynamo in an electric power plant.

LOOKING AHEAD TO UNIT 5 (P. 223). The purpose of the preview of this unit is to get the pupils into an inquiring attitude: What is the difference between the objects that can "do things" and those that cannot? What do the former have that the latter do not? Any devices the teacher can use to this end are appropriate. One very good way is to have the pupils read the preview in the text and then try to answer the questions that are asked.

PROBLEM 1: WHAT IS ENERGY? (P. 225)

This problem serves to bring to full consciousness the reality of something we call energy, something in the universe that makes thing happen, that causes all changes, and without which no changes can occur. The teacher should consider this objective of greater importance than the ability to state in a parrot-like way, "Energy is the capacity to do work." Of course, pupils should understand the latter definition, which is developed in this problem; but they will meet many, many life situations in which they will be able to recognize that a change is occurring, yet will be quite unable to recognize that any work, in the scientific sense, is being accomplished.

The main ideas used to solve this problem are:

1. Knowledge of matter and its different forms does not explain everything.
2. Another part of the universe is the part that causes matter to do things, to change; this part we call energy.
3. Energy is acting all about us all the time.
4. In making an exact study of energy scientists have found it necessary to know about forces. A force is a push or a pull, a tendency to cause motion.
5. In the study of energy scientists also use an exact definition of work. Work is done when a force overcomes some resistance and causes something to move.
6. Energy is defined by scientists as the capacity to do work.

SELF-TESTING EXERCISES (P. 230). 1. In the paragraph written for this exercise a pupil should give evidence that he has grasped the point of the discussion of Problem 1. Mere copying or memorization of text material is not evidence. The exercise will be more effective if, after study and class discussion, the teacher will have all members of the class write their paragraphs at the same time. Each paragraph might well include the scientists' definition and an explanation of what it means in our everyday lives.

2. Three examples of the effects of energy are:

a) The shooting of an arrow from a bow by energy of bent bow.
b) The turning of a water-wheel by the energy of running water.
c) The driving into the ground of a stake by the energy of a heavy object that has been held above it and allowed to fall.

Many other examples may be given and need not be from the book. Any example of something happening is acceptable.

3. A force is something that tends to make objects move, a push or a pull. The push of the wind, the push of moving water, the push or pull of an animal's muscles are all forces. Other examples are the pull of a magnet and gravity of the earth.

4. Work is the moving of something when force is applied. Work is done when a steam engine moves a train; when a hammer drives a nail into a board; when anyone lifts an object, etc.

5. Page 223, paragraph 1. Because it had energy.

P. 223, par. 2. Mary gave energy to the weight (by lifting it).

P. 224, par. 1. Energy.

P. 224. *Legend under Figure 175.* Energy. (Heat energy expanded the concrete and did the work.)

PROBLEMS TO SOLVE (P. 230). 1. Any ten examples of effects of energy from pupils' own observations are acceptable. Special care should be taken to have the examples from real observations.

2. This composition should develop according to an original plan prepared by the pupil. It may well include discussion of the energy obtained in food and used by the bodies of men and animals, the energy of sunlight, the energy used in transportation, communication and manufacturing, the energy of fuels, etc.

3. The five examples of doing work will vary. They should come from reading or other pupils and be similar to the following: (*a*) lifting a suitcase; (*b*) pulling a sled; (*c*) lifting a shovel full of coal; (*d*) pushing a wheel-barrow; (*e*) sweeping the floor.

4. The magnetic force of the earth.

5. The first horse did not do work on the automobile; he did not move it. The two horses did work because they moved automobile.

PROBLEM 2: WHAT DO WE DO WITH ENERGY? (P. 231)

This problem might well be stated, "What kinds of work do we accomplish with energy?" Or, "What kinds of resistance do we overcome with energy?" From the discussion pupils should become aware that all the work in the world is done against a few kinds of force, which they can learn to recognize.

The main ideas developed in discussion of the problem are:

1. Most work is done in overcoming four kinds of resistance: inertia, friction, gravity, and attractions between molecules. (In

reality, friction is of the last type; but pupils would find it hard to understand it in that way.)

2. Inertia is the tendency of all objects to remain as they are, still or in motion in a straight line, unless pushed or pulled by some force.

a) Objects moving in curves tend to fly away from the center (have centrifugal force). This is just the tendency to move in a straight line.

b) We use inertia very often.

c) The real cause of inertia is hard to understand.

3. Friction is the resistance caused by a body or a material moving past another body or material.

4. A great deal of energy is used in lifting objects against the force of gravity.

5. Whenever we pull things apart or cut or break them, we are overcoming the forces that hold molecules together—cohesion between the molecules of the same kind and adhesion between molecules of different kinds.

SELF-TESTING EXERCISES (P. 239). 1. In starting a body the inertia of the body must be overcome. After it is moving, the inertia no longer needs to be overcome to keep it moving.

2. Because the inertia, or tendency of the car to move forward, is overcome by the friction that the body meets.

3. (a) To keep stationary bodies stationary until some force is applied to move them, and (*b*) to keep moving bodies moving until some outside force stops them.

4. Centrifugal force is the force that makes things going around in a circle pull out from the center. Example: mud flying off an automobile wheel (or any other simple case).

5. Because there is much friction between the brakes and the wheels. The friction overcomes the inertia of the moving automobile.

6. Cohesion refers to the force that holds molecules of the same kind of substance together. Adhesion refers to the force that holds molecules of different substances together.

7. (a) inertia; (*b*) friction; (c) gravity; (*d*) molecular attractions.

PROBLEMS TO SOLVE (P. 239). 1. The force of adhesion.

2. We use a hammer in driving nails, etc., because we can make the heavy head of the hammer move very rapidly—give it much inertia of motion. Then when it strikes the nail, the nail is forced in quite a distance before the hammer can stop. Without the tendency to keep moving, the hammer would not drive the nail.

3. Centrifugal force throws the water toward the bottom of the pail and away from the top from which it might spill.

4. Centrifugal force tends to make the car move out sideways away from the center of the curve made by turning the corner, with the result that the car skids.

5. The books remain in place. The friction of the books against the paper was not enough to overcome the inertia of the books and start them moving (with any noticeable speed).

6. When the tree is suddenly shaken, the apples tend to remain in the same place due to inertia. The force caused by this tendency and the motion of the branches breaks the apples from their stems and gravity pulls them to the ground.

7. In starting, a force must be developed that will overcome the inertia of the stopped train. Since this must be a fairly large force and much fuel must be used to develop it, it is expensive to start the train. All the inertia of the moving train must then be overcome to stop it again.

8. Because there is more resistance to overcome when the automobile is standing in mud. The force of cohesion and adhesion of the mud is added to the kinds of resistance that must be overcome when an automobile is standing on pavement.

PROBLEM 3: WHAT ARE THE DIFFERENT FORMS OF ENERGY? (P. 240)

Everyone is quite clearly aware of some of the forms in which energy occurs. That other forms are energy is not equally apparent. Study of the problem should bring out the general nature of all common forms with which the pupils will be concerned.

The main ideas developed in this problem are:

1. Early men could use only the energy that moved their bodies; we now use other forms effectively.
2. Heat is a form of energy.

3. Electric currents are a form of energy.

4. There are two forms of mechanical energy: (*a*) that possessed by moving bodies, called kinetic energy, and (*b*) that possessed by some bodies because of their position, called potential energy. Potential or stored mechanical energy is used a great deal even though it is not very noticeable.

5. A second kind of stored energy is the chemical potential energy of foods, fuels, and explosives, which can be released only when they undergo chemical changes.

6. Energy that travels through space in waves is called radiant energy. We know it by several names: light, radio waves, X-rays, ultra-violet rays, infra-red rays.

SELF-TESTING EXERCISES (P. 248). 1. Forms of energy mentioned: (*a*) heat energy, (*b*) electrical energy, (*c*) mechanical energy [(1) kinetic; (2) potential], (*d*) chemical energy, (*e*) radiant energy.

2. (*a*) Kinetic energy—the energy of matter in motion as, for example, the energy of falling water or of a flying basketball. *b*) Potential energy—the energy stored in a body as, for example, wound-up spring, or a lifted weight.

3. Two ways of storing potential energy in bodies of matter: (*a*) Store energy by means of the position of the body of matter as in lifting a weight in a clock. (*b*) Store energy by bending, stretching, or twisting so that when the objects are released they can do something, such as winding the spring in a clock.

(Potential energy can also be stored by producing a chemical change in material as when plants make sugar and store energy in it.)

4. Electrical energy is used to ring doorbells, etc.

5. (*a*) Radiant energy passes through empty space, while other types of energy cannot leave the bodies of matter in which they exist. *b*) Three varieties of radiant energy are: light, radio waves, X-rays.

6. Chemical energy is energy that has been stored in a substance during the process of making the substance. A chemical change in the substance releases it again. Coal and sugar have much chemical energy.

7. (*a*) Heat energy, (*b*) mechanical potential, (*c*) radiant energy, (*d*) kinetic, (*e*) chemical potential, (*f*) electric.

PROBLEMS TO SOLVE (P. 249). 1. Potential energy.

2. Chemical energy.

3. When you are climbing the stairs, you are using chemical and kinetic energy. You are using chemical energy because the source of your energy is food material stored in your body. It is being "burned," and energy is released. You must move to climb. You climb with the help of kinetic energy. When your body has reached the top of the stairs, it has gained potential energy.

4. Kinds of energy illustrated on pages 223-225. Page 223, paragraph 1: Kinetic energy; p. 223, par. 2: Potential energy in the weight at the top of the case. It is changed to kinetic energy as the weight falls to the bottom of the case. The swinging pendulum has both potential and kinetic energy: potential at the top of the swing on either side and kinetic in the center of the swing.

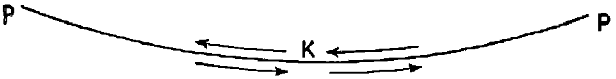

FIG. 12

P. 223, par. 3: Potential energy stored in the steam and changed to kinetic energy as it began to move the train. Kinetic energy all the time the train was moving.

P. 224, *Legend under Figure 175:* Radiant energy of the sunlight changed to heat in the concrete pavement, caused it to expand, lift, and break.

5. When a diver jumps on a spring-board, he pushes the board down and the effect is similar to tightening a spring. He is giving potential energy to the board when it is in its new position. When the board is released, the potential energy is changed to kinetic energy. This kinetic energy is transmitted to the diver and gives him the motion he needs for making his dive.

6. Potential energy. Because the air is under pressure and is capable of doing work when it is released.

7. It is changed to kinetic energy during the fall and becomes heat when the weight strikes the ground.

8. Weight B could be lifted higher than A, or it could be heavier than A. In both these cases it would have more potential energy than A.

PROBLEM 4: HOW DO WE CHANGE ONE FORM OF ENERGY INTO ANOTHER? (P. 249)

The natural climax of a study of energy is the realization that energy undergoes constant transformation. Only in the light of that realization can the modern use of energy be made comprehensible. The pupils should be kept thinking about this problem until they can "see" the energy transformations that are constantly occurring all about them.

The main ideas developed in discussing this problem are:

1. Each form of energy can change into another form when the conditions are favorable.
2. Energy transformations are commonplace happenings; they are going on all about us and even in us.
3. During the transformation of energy none of the energy is destroyed. All of it appears again in some form; but we are unable to have all the energy that is transformed take a useful form. Some is always wasted.

EXPERIMENT 32. WHAT ARE SOME WAYS OF CHANGING ONE FORM OF ENERGY INTO ANOTHER? (P. 250). The apparatus and materials needed are:

Piece of lead size of a coin
Hammer
Something heavy and hard such as a large piece of metal or a strong stone to pound on
A coin
Matches
Test-tube with steam-tight stopper to fit
Test-tube holder
Water
Dry cell
Tinfoil or fine iron wire
Small electric motor

The experiments of this group are easily carried out. Each energy change that is demonstrated is one that is very common. As each part is completed, the pupils should be encouraged to describe similar changes they have observed.

a) The piece of lead becomes warm. The kinetic energy of the hammer becomes heat energy in the lead.

b) The change here is the same as in part a, except that the transformation is caused by friction rather than by impact.

c) The wood of the match possesses chemical energy. Burning of the match changes it into heat and light energy.
d) Heat energy boils the water, and the cork receives kinetic energy.
e) The wire should get hot. If just the right length is used, it may become red hot or even melt. If tinfoil is used, it should get hot and melt. If these materials glow, some of the energy is becoming light energy. Chemical energy of the cell becomes electrical energy and later heat (and light).
f) When the motor runs, the chemical energy of the dry cell changes into electrical energy and, later, into kinetic energy.

SELF-TESTING EXERCISES (P. 254). 1. (A) *Mechanical potential:* (*1*) Changed to kinetic when the water stored above a dam is allowed to fall over the dam. (2) The potential energy of a bent bow is changed to the kinetic energy of the moving arrow.

B) *Kinetic:* (*1*) In the swinging of a pendulum the kinetic energy of the motion in the middle of the swing is changed to potential energy by the time the weight gets to the highest part of the swing. (See Figure 12, page 147 of *Guidebook.*) (2) Kinetic energy of a hammer is changed to heat when the hammer strikes a nail. (3) A ball is thrown on a roof and stays there, the kinetic energy of the moving ball is changed to potential energy of the stationary ball.

C) *Chemical energy:* (*1*) When food in our bodies is oxidized, some of the chemical energy is changed to kinetic energy as we move. (2) The chemical energy stored in coal is changed to heat energy when the coal is burned in the furnace.

D) *Heat energy:* (*1*) Heat energy of burning coal transferred into the kinetic energy of a moving locomotive. (2) Heat of burning gasoline changed to kinetic energy of moving automobile.

E) *Electric energy:* (*1*) Electric energy is changed to heat energy in electric toasters, etc. (2) Electric energy is changed to light energy in electric light bulbs, etc. (3) Electric energy is changed to kinetic energy in trolley cars, etc., using electricity for power.

F) *Radiant energy:* (*1*) Light energy is transformed into potential chemical energy when green plants make sugar or starch. (2) Radiant energy from the sun is changed to heat energy when it is absorbed by some material.

3. It is important because we are able to use many sources of energy to help us do work that would not be available if one kind of energy could not be transformed into another. Examples similar to those given in Exercise 1 will show that transformation of energy is important in everyday life.

PROBLEMS TO SOLVE (P. 255). 1. As you wind a grandfather's clock, you are changing kinetic energy into mechanical potential energy in the weight. As the clock runs, this potential energy is being transformed back again to kinetic energy and finally into heat energy through friction.

2. Radiant energy from the sun was transformed to heat energy in the cement. When expansion became great enough, the pavement cracked; and the potential energy was changed to kinetic energy that pushed it up into the air.

3. (a) A machine is usually transforming one kind of energy into another. If it is not supplied with more energy from the outside, it will stop when it has transformed into another kind all of the energy that makes it go.

b) It encounters various kinds of resistance that cause it to stop.

4. We want a change from chemical potential energy to light energy. Most of the energy is wasted as heat energy.

5. Kinetic energy of the train is changed into heat energy in the bearing.

6. The radiant energy of the sun is changed to heat energy. This raises the temperature of the wood to its kindling temperature, and it burns with a change from chemical potential energy to heat and light energy.

7. The chemical energy of the gasoline is changed to heat energy and to kinetic energy. It is finally changed back into heat energy by friction of the car.

LOOKING BACK AT UNIT 5 (P. 255). 1. Main ideas to be included in this paragraph:

a) Energy is something that makes matter do things and change; or, stated in another way, it is the capacity to do work.

b) Whenever anything moves, it is being pushed or pulled by a force.

c) Force may be exerted whether anything is moved or not.
d) Work is done when a force moves something.
e) Most work is done in overcoming resistance due to inertia, friction, gravity, and the forces holding molecules of matter together (adhesion and cohesion).
f) Energy has different forms: mechanically stored or potential, kinetic, electric, chemical (potential) radiant, heat.
g) Energy may be changed from one form to another.
h) Energy can never be made or destroyed. When a certain amount disappears, an equivalent amount of another form must appear.

2. *Inertia* is the tendency of any object to stay still if still, or, if moving, to keep on moving in a straight line.

Friction is the resistance to motion that is present when two objects or two materials rub together.

Cohesion is the tendency of parts of a material to hold together—the force that holds molecules of the same kind together.

Energy is what makes thing happen—the capacity to do work.

Kinetic energy is the energy possessed by a moving object because of its motion.

Potential energy is energy that is stored in some way; it is not noticeable.

Transformation of energy is the change of one kind of energy into another, as when the energy of an electric current changes into heat and light in a light bulb.

Conservation of energy is a scientists' name for the "rule" of nature by which each bit of energy that is transformed changes into an equivalent amount of another form; none is ever destroyed or created.

Adhesion is the tendency of different kinds of materials to stick together—the force that holds molecules of different kinds together.

Radiant energy is energy that "shines" out from an object through the space around it; it is energy that radiates.

Chemical energy is energy like that which is stored in food materials and which can be gotten out only when the material changes chemically.

Centrifugal force is the outward pull of an object that is moving in a circular or curved path.

ADDITIONAL EXERCISES (P. 256). 1. Energy changes in an automobile:

PART OF CAR	CHANGE OF ENERGY	
	FROM	INTO
Engine	Chemical energy of gasoline	Heat
Engine	Heat	Kinetic
Tires	Kinetic	Heat
Brakes	Kinetic	Heat
Springs, when bent	Kinetic	Potential
Springs, when straightening	Potential	Kinetic
Battery	Chemical	Electric
Spark plug	Electric	Heat and light
Head lights	Electric	Light and heat
Starter	Electric	Kinetic
Generator	Kinetic	Electric

2. Any reports on this exercise will vary from pupil to pupil.

3. A perpetual-motion machine is impossible because of the existence of friction and the law of conservation of energy. Every machine must have friction. Friction always converts some kinetic energy to heat and slows the machine. If a machine does work, some of its energy must be used to do the work and the loss will slow the machine, finally stopping it.

4. Potential energy. It receives its energy when it is being pumped into the tire with a hand pump, or when it is forced into a container under pressure.

5. Work is measured by measuring the amount of force that acts and the distance it moves something. The two are multiplied to find the total work done. Thus if the force is measured in pounds and the distance in feet, the units are foot-pounds. A weight of five pounds lifted three feet requires fifteen foot-pounds of work.

6. Forms of energy needed to operate a radio receiving set are: a) Electric energy. Provides heat to operate tubes and energy used by loudspeaker in producing sounds.

b) Radiant energy (radio waves). Controls the set so that it produces the correct sounds.

7. Effects of the energy of the sun on the earth: (*a*) heats the earth; (*b*) causes winds; (*c*) causes rain, etc.; (*d*) supplies energy for green plants to make food on which all life on the earth depends; (*e*) the stores of this energy used by plants and animals in the past are now available to us in forms of coal and oil.

8. The survey should include water power, fuels (wood, coal, coke, oil, gas, gasoline), wind, electrical (followed back to its source).

9. Because energy must be used to overcome the resistance of gravity, which tends to pull it downhill.

10. Auto D could be heavier, or it could be moving faster.

11. Hitting the end of the handle drives the handle forward. The inertia of the moving handle tends to keep it going, while the inertia of the resting hammer head tends to keep it at rest. The two opposing tendencies force the handle in very tight.

12. The water lessens the cohesive force between the molecules of paper.

13. The pounding brings the molecules close enough together so that the cohesive force between the molecules of the two pieces of lead is sufficient to make them stick together.

VISUAL MATERIAL FOR UNIT 5

MOTION PICTURES

Encyclopaedia Britannica Films
"Energy from Sunlight"
"Energy and its Transformations"

FILMSTRIP

Society for Visual Education
"Energy"

UNIT 6

How Do We Control Heat?

Function and Scope of Unit 6. Hardly a person can live for a day without using, either consciously or unconsciously, the principles of heat control. This use is much more effective if the principles are well understood and can be consciously applied whenever problem situations arise. In accord with the plan of organization used in this series of science books, the first two problems are focused upon the development of the fundamental concepts involved, (1) the three methods of transfer: conduction, convection and radiation, and (2) the transformation of energy when a material changes its state. Problems 3 and 4 show how these principles are applied in regulating heat in the home. Refer to the graph on page 155.

Pupils will gain a greater degree of understanding of this unit if they have the background necessary to answer some of the Introductory Exercises.

Book 1

Unit 3. The three states of matter.
Units 3 and 4. The molecular explanation of matter.
Unit 4. Changes of state.
Unit 6. Fire and its control.

Book 2

Unit 1. Nature and distance of sun.
Unit 4. Circulation of fluids caused by differences of temperature.
Unit 5. The common forms of energy and transformations of energy.

Introductory Exercises (p. 258). 1. No. It creates motion in the air. This motion carries off the damp layers of air around our bodies, making evaporation of moisture from the surface of our bodies more rapid. This more rapid evaporation cools our bodies.

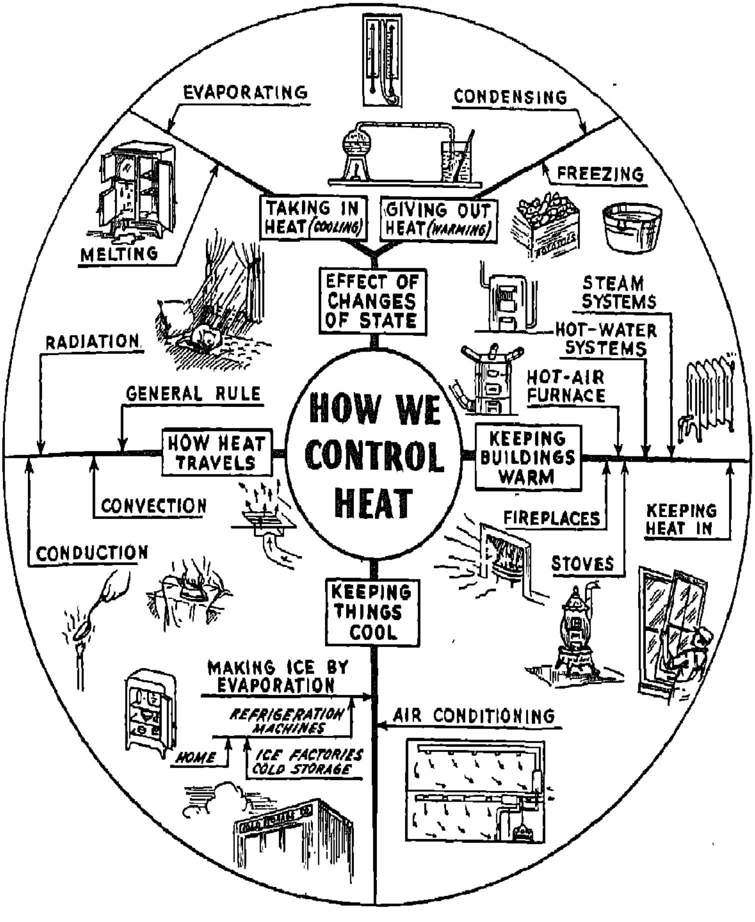

FIG. 13. GRAPH OF THE SUBJECT MATTER OF UNIT 6

2. They begin to move faster.

*3. Because the currents of gas from the burning kindling carry more heat upward than can be transferred downward.

*4. Into the air or space next to the liquid. The molecules of the liquid pass off from the surface of the liquid into the air until the liquid seems to have disappeared.

*5. We mean that the gas changes from its gaseous state to the liquid state.

*6. No. Steam is colorless and we do not see it. What we see coming from the spout of a tea kettle is condensed steam. When the particles of steam reach the colder air beyond the spout, they are changed to liquid water and suspended in the air as a fine visible cloud. The clear space between this cloud and the spout is steam.

7. Because wood and hard rubber are poor conductors of heat and these handles make it possible to pick up a utensil that has been in something hot. Without these the heat from the food would be conducted up the handle and make it impossible to pick them up.

8. Beginning at the place being heated, each molecule by vibrating rapidly, causes the next to vibrate rapidly and so on until the entire wire is hot. This process may or may not be called "moving of heat along the wire."

9. Because glass is a material that allows radiant heat to pass through it without absorbing much of it. For this reason the glass remains cold while your body absorbs heat.

10. On a humid day evaporation of moisture from the surface of the body is much less rapid than on a dry day. Since evaporation cools our bodies, we are warmer when evaporation is decreased.

11. More. As ice melts it takes more heat from the refrigerator to change its state than ice water takes since it is not changing its state.

12. In an electric refrigerator the cooling is done by the evaporation of a liquid (usually sulphur dioxide or ammonia). When a liquid changes to a gas, heat is required. The heat comes from the inside of the refrigerator box, and as it passes from the box to the evaporating liquid, the box is cooled.

13. A home can at least be kept comfortable by using insulating materials in the walls and roof of the house. These materials are poor conductors of heat. In the summer they prevent the heat from passing through the walls or roof and making the house too hot. In winter these materials prevent the loss of heat provided by heating systems in the house. Without insulation much of the heat passes out through the walls and the house becomes cold.

14. A hot-water heating system carries heat by means of hot water. The water is heated by the fire in the furnace or stove and carried in pipes to the rooms to be heated. In each room the water circulates through radiators, from which heat is conducted and radiated into the room.

LOOKING AHEAD TO UNIT 6 (P. 259). This section raises some of the problems that are to be solved in the unit. After the pupils have read it, it is suggested that a review of the assumptions of the molecular theory be conducted, since this theory is used to explain the transfer of heat and change of state. A discussion may also be held concerning the changes that have taken place in methods of heating since the early days of our country.

PROBLEM 1: HOW DOES HEAT TRAVEL FROM ONE PLACE TO ANOTHER? (P. 261)

The purpose of this problem is to secure an understanding of the three methods of heat transfer: conduction, convection, and radiation. The main ideas of Problem 1 are:

1. Heat is always moving from places of higher temperature to places of lower temperature.
2. Heat moves right through materials by a process called conduction; this process seems to be due to the more rapidly moving molecules striking against their neighbors and causing them to begin to move more rapidly.
3. Materials differ greatly in the rate at which heat is transferred through them, some being very good conductors and others very poor conductors, or insulators.
4. Fluids carry heat from one place to another by circulating under the influence of differences of temperature—by convection.
5. Heat moves through the space between warm objects and cooler ones by a process called radiation; in radiating it changes into radiant energy and then back again into heat when it is absorbed by another material.

6. Materials differ greatly in their ability to tra absorb radiant energy.

EXPERIMENT 33. HOW IS A PIECE OF METAL HEATE The apparatus and materials needed are: large na burner or other source of heat.

A striking way of demonstrating conduction is to of candle wax at intervals along the nail. They wil drop, beginning with the spot nearest the heat. If metal about one-half inch wide is used and held zontal position, heads of matches can be placed at var

SELF-TESTING EXERCISES (P. 265). 1. When one en rod is heated, the molecules of metal in the rod begin to rapidly. As they move more rapidly, the temperature rises. As the molecules in the end move about rapidly, into each other. As the molecules bump into the ones other, the motion is transferred to the molecules at th of the rod, and the rod feels hot at the end away from th heated.

2. (a) We use materials that are good conductors making heating apparatus, for making cooking utensils ar heating and cooking our food, and for any use in which transfer heat. For example, iron stoves make very goo heat for a room because the iron is a good conductor, an is conducted from the fire inside to the air around the st b) Materials that are poor conductors are used when wish heat to be conducted. They are used to prevent the when it is wished to conserve heat and to prevent the of heat as a safety measure. Houses are insulated with m prevent the heat from the furnace in winter from bein through the walls and being wasted. Wooden handle on cooking spoons, heating pipes are covered with asbe

PROBLEMS TO SOLVE (P. 265). 1. (a) *Good conduc* num pan, iron shovel. *Poor conductors:* bakelite cup, porcelain knob, brick.
b) To find out if a material is a good conductor, heat the material and see if other parts of the material get pare results with those obtained with a good conductor.

2. The blanket is a poor conductor of heat and prevents the heat of our bodies from escaping into the air. In the same way it keeps the ice cool by preventing heat from outside from reaching ice.

3. A paper bucket because paper is a much poorer conductor of heat than tin and would prevent heat from reaching the ice cream.

4. Ruffling up the feathers makes a layer of air between the feathers. Air is a poor conductor and increases the insulation against loss of heat from the bird's body.

5. The freezing of the ice cream is brought about by the loss of heat inside the container holding the ice-cream mixture to the ice on the outside. The inside can is made of metal, a good conductor, to facilitate the passage of heat from the cream. The outside pail is made of wood to prevent heat from the outside from entering the pail and melting the ice. If this happened, heat would not be taken from the cream to melt the ice and the cream would not freeze.

6. If the paper is wrapped around an iron rod and held in a flame, the iron will conduct the heat away; so the temperature of the paper will not be raised to the scorching point. Wood is a poor conductor of heat; so the heat from the flame will not be conducted away, and the paper will scorch.

SELF-TESTING EXERCISES (P. 267). 1. The heat from the fire passes through the metal of the stove by conduction into the air around the stove. The air near the stove expands and becomes lighter than the cool air near the window. This air sinks, forcing the air around the stove to the ceiling. This movement of the air is a convection current that continues as long as the air near the stove is kept warmer than the air around it. The person near the window receives some of the warm air carried by the convection current. (See Figure 203, page 266 of text.)

2. Near the ceiling. The warm air expands and is pushed toward the ceiling by the heavier cold air as it sinks to the floor.

PROBLEMS TO SOLVE (P. 267). 1. Yes. If heat is applied at the top, the warm water stays at the top, since it is lighter than the cold water beneath it. But if heat is applied at the bottom, the warm water is pushed up by the cold.

2. The pull of gravity on the heavier cool air in the house forces the warm air up into the house as the warm air expands and becomes lighter. As the warm air gives up its heat and becomes cool, it sinks

again to the furnace, where it is reheated. If the furnace were at the top of the house, only the air at the top would be heated and the rest of the air would remain cold.

3. Open the windows both at the top and at the bottom. The cold air enters at the bottom and the hot air escapes at the top, resulting in a complete change of air and cooling of the room.

4. When a fire is started around the pipe at A, the heat is carried by conduction through the metal to the water in the pipe. As the water is heated, it expands and becomes lighter. The pressure of the heavier cold water in the tank pushes the hot water up into the top of the tank from the side pipe, and the tank feels warm at B. The new supply of cold water at A is heated and pushed up. Gradually all the cold water has been heated in this way. This method of heat transfer is convection, and the motion will continue as long as there is a difference of temperature in the tank and pipe.

EXPERIMENT 34. HOW IS HEAT TRANSFERRED BY RADIATION? (P. 268). The apparatus and materials needed are: electric radiator, toaster, or candle; incense or cork.

No difficulty will be experienced with this experiment. Pupils may be asked how standing near a camp fire on a cold day is like this experiment.

EXPERIMENT 35. HOW IS RADIANT ENERGY CHANGED TO HEAT? (P. 269). The apparatus and materials needed are:

Two test-tubes
Test-tube rack or other holder
Candle
Water

It is not necessary to place water in the test tubes, since satisfactory results may be obtained by taking the temperature of the air in the tubes after exposing them to the sunlight. If water is used, care should be taken to have it at the same temperature as the temperature of the room at the start of the experiment. It will be obvious that the experiment should be carried out in the absence of a strong draft.

SELF-TESTING EXERCISES (P. 270). 1. By the radiant energy radiated by the fire. This radiant energy is changed to heat when it strikes a person, and one is warmed by it. The air in the room is not warmed by this radiant energy because it is not absorbed and changed; therefore one's back is cold.

2. Radiation is really a form of energy that can change into heat when it is absorbed; or it is a process by which energy of hot objects reaches other and cooler objects.

3. No molecules are needed for the transfer of heat by radiation.

PROBLEMS TO SOLVE (P. 271). 1. Examples will be individual.

2. Yes. Radiant energy must be changed to heat by being absorbed by some material. Since there is no material in the space between earth's atmosphere and sun, this space is not warmed.

3. Yes. By conduction the hot metal of the stove heats the molecules of air that are touching the stove. The warming of this air sets up a convection current, and by convection the warm air is carried to other parts of the room. The stove, being hotter than surrounding materials, also gives out radiant energy.

4. Dirty snow absorbs more of the radiant energy of the sun than clean snow and therefore has more heat to melt the snow. The dead leaves, which are dark, also absorb more radiant energy and by conduction transfer heat to the snow beneath it.

5. White does not absorb so much of the radiant energy of the sun as dark material does. Instead it reflects a large part of the radiant energy of the sun without changing it to heat. For this reason white clothes are cooler than dark ones.

6. (a) The vacuum prevents heat from passing from the inner container to the outer by conduction. It also prevents convection currents from being set up.

b) By radiation. This method of transfer is prevented by silvering the inside and outside walls of the inner bottle so that radiant energy will be reflected instead of absorbed.

c) Cork is a poor conductor of heat and the use of this material for a stopper prevents the loss of heat that would occur by conduction from a metal stopper.

d) These same factors that keep heat from passing from the inside of the bottle to the outside keep heat from passing into the bottle.

7. Fill a thermos bottle with hot water and record the temperature of the water. At intervals take the temperature of the water and record the time and temperature at each reading.

PROBLEM 2: WHAT HAPPENS TO HEAT WHEN A MATERIAL CHANGES FROM ONE STATE TO ANOTHER? (P. 272)

Consideration of this problem should lead to an understanding of the principles that describe the gain or loss of heat that takes place in a material when it changes state. Unless these principles are understood it will be impossible for the pupil to understand steam heating and refrigeration.

The main ideas of the problem are:

1. Whenever a solid is changed to a liquid, heat energy is required to pull the molecules away from each other, that is, heat is absorbed.
2. When a liquid is changed to a solid, heat is given off.
3. The quantity of heat required to change a solid to a liquid is equal to the quantity of heat given out when a liquid changes to a solid.
4. Heat is required to change a liquid to a gas.
   a) The heat required to change a liquid to a gas comes from surrounding materials, which are therefore cooled.
   b) The more rapid the evaporation, the greater the cooling.
   c) The less vapor there is in the space above a liquid, the more rapid the rate of evaporation.
   d) Evaporation takes place at all temperatures. The higher the temperature, the more rapid the rate.
   e) After water reaches the boiling point, additional heat is used to change the water to steam, but the temperature does not rise.
5. When a vapor condenses, heat is given out.
6. The quantity of heat required to vaporize a liquid is equal to the quantity of heat given off when the vapor condenses.

EXPERIMENT 36. WHAT HAPPENS WHEN A MIXTURE OF ICE AND WATER IS HEATED? (P. 273). The apparatus and materials needed are:

Beaker (or cup)
Wire gauze
Thermometer
Ice
Ring and ringstand (or other support)
Bunsen burner (or other source of heat)

No difficulty will be experienced with this experiment. An experiment along the same lines may be done by adding ice to water at room temperature. The water will cool to approximately 32° F., and then the temperature will remain stationary until the ice is all melted. After the water is cooled to about freezing temperature, additional heat to melt the ice comes from surrounding materials.

SELF-TESTING EXERCISES (P. 275). 1. Because it requires so much heat to melt it. Therefore it takes a great deal of heat from the surrounding liquid.

2. Pulling the molecules of the ice apart.

3. Since more energy is needed to melt the ice than is needed by the ice water, more heat is taken from the water by ice than by ice water. Read the legend of Figure 210, page 274.

PROBLEMS TO SOLVE (P. 275). 1. No. The heat required by the ice for melting is taken from the food, and if the ice is prevented from melting, it will not take so much heat from the food.

2. The melting ice takes more heat from the air than is being taken from the air in the inland regions. Thus the air is cooler where ice is melting.

3. One way of doing this experiment is to place an equal quantity of water at the same temperature in two pans. Then add a pound of ice to one pan and a pound of water to another pan. Observe the temperature in both pans when the ice has melted.

4. Because so much heat is used in changing ice to water. It takes a long time for the large amounts of ice to receive sufficient heat by conduction, convection, and radiation.

EXPERIMENT 37. DOES WATER KEEP GETTING COLDER WHILE IT IS FREEZING? (P. 276). The apparatus and materials needed:

Test-tube or small bottle
Water
Thermometer
Cracked ice
Common salt
Container for ice and salt

No difficulty will be experienced with this experiment. Pupils often get the idea that ice remains at 32° F. regardless of outside temperature. If the temperature of the ice is taken for several minutes, this can be shown to be false.

SELF-TESTING EXERCISES (P. 278). 1. All the time that the water is freezing it is giving out heat. This keeps the temperature at 32° F.

2. When water freezes it gives out heat; this heat helps keep the air in a cellar warmer than the air outdoors on a very cold night.

3. As the water in the trays freezes, heat is given out, warming the air around the trays. As the air gets warmer, less heat comes off from the water. The freezing process is slowed down.

EXPERIMENT 38. DOES AN EVAPORATING LIQUID TAKE HEAT FROM THE THINGS AROUND IT? (P. 278). The apparatus and materials needed are:

Stoppered bottles of ether, alcohol, and water (one will do but see Part e)

One-holed stopper to fit bottles

Thermometer that fits hole

Thin cloth or cotton

a) Ether and alcohol evaporate more quickly than water. The results will be more pronounced if they are used.

b) The air in the bottle above the liquid is saturated with vapor and no evaporation will take place.

c) The temperature will depend upon the kind of liquid used and the relative humidity of the air.

d) Fanning will increase the rate of evaporation and the fall in temperature will be more rapid.

e) Temperature fall will be greater in alcohol than in water and greater with ether than with alcohol.

SELF-TESTING EXERCISES (P. 282). 1. The evaporation of water around a wet-bulb thermometer makes it cooler than the dry-bulb because heat is taken out of the mercury.

2. The wet- and dry-bulbs show the same temperature when the air is completely full of water vapor. At this time there would be no evaporation from the wet-bulb, and it would record the same temperature as the dry-bulb.

3. It is useful in keeping us cool. The evaporation of perspiration from our bodies cools our bodies.

4. When he got out of the water, the water on his body began to evaporate and this evaporation made him feel cold.

5. Drawing in the breath brings about evaporation of moisture from surface of tongue, and this makes tongue feel cool.

Problems to Solve (p. 282). 1. No. Fanning keeps one cool by removing the layer of moisture-saturated air from around the body, and allowing more perspiration to evaporate. But if the air is already saturated with moisture, there is no dry air to replace the layer removed by fanning, and evaporation can take place no more readily than before fanning.

2. The water inside will be cool. The evaporation of moisture from the outer surface takes heat from the bag or jar and keeps the contents cool.

3. *Fig. 215, p. 282.* On these uncomfortable days the humidity is high. That is, there is a large amount of water vapor in the air which prevents the evaporation of the perspiration from our bodies. On dry days the perspiration can evaporate. This takes heat from the body and we feel comfortable.

4. A fan creates a current of air. This current of air removes the layer of saturated air that surrounds us when we are perspiring on a hot day. When this layer of air has been removed, the perspiration from our bodies is free to evaporate and we feel cooler.

5. Dry ice evaporates very rapidly. For this process heat energy is needed. As it does so, it takes up so much heat for itself that it stays at the very low temperature.

6. No. The temperature of the boiling water remains the same regardless of how high or how low the fire is. The boiling will be more rapid with a high flame, but the temperature of the water remains the same.

Experiment 39. Which Can Warm Things More, Boiling Water or Steam? (p. 283). The apparatus and materials needed are:

Can
Balance
Water
Flask
Glass tubing
Thermometer
Bunsen burner or other source of heat

The number of calories can be computed if desired. For each degree rise in temperature, one calorie is required for each cubic centimeter, or 300 calories for the 300 cubic centimeters of water used. If a balance is not available, steam can be passed into the water for a few minutes and then the water in the can can be measured, showing the number of cubic centimeters of condensed steam added. Then the number of calories can be computed. (When steam changes to water, it gives out 539 calories per gram.)

SELF-TESTING EXERCISES (P. 285). 1. Steam will cause a more severe burn than boiling water because more heat is given to the body when the steam condenses.

2. The room has been warmed by the heat that comes out of the water when it condenses from the steam to the liquid form.

PROBLEMS TO SOLVE (P. 285). 1. It is expensive because it requires a large plant and equipment and a large amount of fuel for heating the water to the gaseous state. It is slow because the water has to change its state twice in the process.

2. The room having hot water sent into the radiators will require more pounds of water to warm it. When steam condenses to form water, the heat required to evaporate it is given out. Therefore, less steam is required to give the same amount of heat as given out by hot water.

3. When it is being changed from a liquid to a vapor.

PROBLEM 3: HOW DO WE KEEP OUR BUILDINGS WARM? (P. 286)

In this problem, the principles presented in Problems 1 and 2 are applied to explain the operation of various kinds of heating devices.

The main ideas of Problem 3 are:

1. Fireplaces heat rooms mainly by radiation (except in the ventilating fireplace in which a convection current is set up).
2. Stoves heat rooms by all three methods of heat transfer.
3. Hot-water and hot-air furnaces transfer heat by convection currents.
4. Steam furnaces transfer heat by forcing steam through pipes to radiators. When the steam condenses in the radiators, it gives up a very large amount of heat to the air in the room.
5. Heat losses from buildings can be reduced by insulating materials that are poor conductors of heat and by tight construction.

Self-Testing Exercises (p. 293). 1. Because not so much of the heat of the fire is lost by going up the chimney. Since the metal of the stove is an excellent conductor of heat, the heat that would be wasted in a fireplace by going up the chimney heats the metal of the stove, and then by conduction the air around the stove.

2. They both operate by means of convection currents. They are different in that the hot-water system consists of a system of closed pipes which warm the air near radiators, while in the hot-air system, the convection current of air warms the room.

3. In condensing to water in the radiator, steam gives up much more heat to the metal in the radiator than is given to it by the hot water.

4. Choice of heating systems depends upon kind of house, climate, and relative cost of buying and operating. Pupils should weigh the advantages and disadvantages of different systems and be able to support their choice with good reasons.

Problems to Solve (p. 293). 1. The hot-air system.

2. In most communities the hot-air system is the most common.

3. It brings oxygen (in fresh air) to the fire so that it can burn.

4. In a vapor or low-pressure system, the pressure of the air above the water in the boiler is reduced so that the water can boil at a lower temperature. Thus the vapor can go to the radiators at a much lower temperature than it does in an ordinary steam system. Heat is secured more quickly, and it is easier to control the temperature of the room. In this way the vapor system has the advantages of the hot-water system.

5. These will vary with the manufacturer.

6. The electric stoker is illustrated and discussed in *Science Problems, Book 1*, page 211.

7. Refer to *Science Problems, Book 1*, page 210.

Self-Testing Exercises (p. 295). 1. Heat can be lost from buildings (a) by being conducted through walls and windows; (b) by being carried out through cracks and porous walls; (c) by being radiated through windows.

2. The most important ways to prevent loss of heat are: (a) to stop up cracks and put weather strips on the windows; (b) to use storm windows; (c) to insulate the building with non-conductors.

PROBLEMS TO SOLVE (P. 295). 1. Pupils should be directed to look for possible losses stated in Self-Testing Exercise 1 above.

2. Common insulating materials: asbestos, cork, gypsum, hair and fibers of sugar cane, wood straw, flax made into wallboard, and other forms of material that can be placed in walls and under the roofs. These are poor conductors of heat because the materials themselves are poor conductors, and because they are so porous that they hold large quantities of dead air, which is also a very poor conductor of heat.

3. Storm windows reduce the loss of heat through the windows. The air near the window is not cooled and does not set up a convection current. Cold air does not sink to the floor and push up the warm air there. Therefore the air remains warmer near the floor.

The diagram will show a downward convection current near windows in a room without storm windows. It would also show this with storm windows if the hot-air pipe is on an inside wall. If hot-air pipe is on an outside wall, the convection current would move in an upward direction.

4. Insulate the roof so that the heat of the sun could not pass through it so readily. Thus the heat is kept outside and the attic remains cooler. Open the windows to allow for circulation at night.

5. The rooms above the basement act as insulation and keep the heat from the sun from penetrating to the basement and warming it.

PROBLEM 4: HOW DO WE KEEP THINGS COOL IN WARM WEATHER? (P. 296)

This problem is the reverse of Problem 3, where heat was to be supplied. In this one heat is to be removed for refrigeration, ice-making, and summer air-conditioning. Insulation is shown to be just as important for cooling as for heating.

The main ideas of the problem are:

1. Evaporation of a liquid removes heat from the liquid and, if sufficiently rapid, may result in the freezing of the liquid.

2. Electric refrigerators freeze ice by securing the rapid evaporation of a liquid that removes heat from the water.

3. Cold-storage plants are cooled by brine that has been cooled below freezing by the evaporation of liquid ammonia.

4. Air-conditioning includes keeping the proper temperature, warm in winter and cool in summer; keeping the amount of water vapor at the correct level; and keeping the air free from dust.

Experiment 40. How Can Ice Be Made By Evaporation? (p. 298). The apparatus and materials needed are:

Water
Cork
Watch glass
Ether
Cardboard or paper for fan
Thermometer

The conditions under which ice freezes in an electric refrigerator can be demonstrated more effectively if a vacuum pump is available. Do the experiment as directed, but place the glass under a bell jar and exhaust the air. The lowered air pressure results in an increase in the rate of evaporation.

Self-Testing Exercises (p. 302). 1. The evaporator is made very cold by the evaporation of a liquid held between the walls of the evaporator. This liquid is one that evaporates easily. The heat necessary for evaporation comes from the water in the ice-cube trays and from the food and air in the refrigerator. As rapid evaporation occurs, the evaporator becomes very cold, the water in the trays freezes, and the ice-box compartments become cold.

2. A fan is used to remove warm air from around the condenser and to replace this warm air with the cool air that will take up heat from the compressing gas in the condenser. If this heat were not taken up, it would prevent condensation from taking place.

3. The motor is necessary to run the pump that moves the vapor from the evaporator to the condenser, where it is changed into liquid form to be used again in the evaporator.

4. Because the cooling process involves the taking up of heat from the surroundings. As long as the ice cubes are solid, they are not taking up heat. The cooling is done by the heat taken up by the liquid in the evaporator as it evaporates.

Problems to Solve (p. 302). 1. Because cork is a poor conductor of heat and all the heat necessary for the evaporation of the ether would come from the water, allowing the water to freeze more quickly.

2. (a) *Heat is in the water in the ice-cube trays.*
b) By conduction the heat passes through the metal into the evaporator, where it is absorbed by the evaporating liquid.
c) In the vaporized evaporating fluid it is carried by circulation to the condenser.
d) From the condenser it passes by conduction to the outside of the condenser pipes and into the air.
e) A fan helps remove the heat by circulation into the air away from the pipes. In some types of refrigerators convection currents also carry the heat away, and no fan is used.

3. When no more heat is removed from the inside of the refrigerator by the machinery or by the melting of ice, the heat that is always being conducted through the refrigerator walls warms the inside of the "box."

SELF-TESTING EXERCISES (P. 304). 1. Complete air-conditioning of a building includes keeping the proper temperature, warm in winter and cool in summer; keeping the amount of water vapor at the correct level; and keeping the air free from dust.

2. Air is usually cooled in a way similar to that in an ordinary refrigerator. A machine containing some evaporating fluid cools brine, which is run through a series of pipes. The air is blown over these pipes and cooled. Sometimes water is cooled and sprayed into the air. This helps keep the proper amount of moisture in the air, as well as the correct temperature.

3. By cooling the air so that the excess moisture condenses.

PROBLEMS TO SOLVE (P. 304). 1. Reference book exercise on refrigerator cars and refrigerated trucks.

2. Trip to see air-conditioning machinery in some building.

LOOKING BACK AT UNIT 6 (P. 304). 1. (a) Heat moves from places of higher temperature to places of lower temperature.
b) Heat moves by means of conduction, convection, and radiation.
c) Some materials are good conductors of heat, and others poor conductors.
d) Materials differ in their ability to transmit and absorb radiant energy.
e) When a material changes state, heat is taken in or given out.

f) Buildings are heated by using one or more of the three methods of heat transfer.

g) Buildings are kept warm or cool by applying a knowledge of insulating material.

h) Refrigerators, rooms, etc., are cooled by applying knowledge of what happens to heat when materials undergo change of state.

3. *Conduction* is the process of passing heat from one molecule to another.

Convection is the transfer of heat by the movement of molecules from one place to another.

Radiation is the transfer of radiant energy.

Heat insulation is the prevention of the transfer of heat by the use of non-conductors of heat.

An *expansion tank* is used in a hot-water heating system to prevent water from overflowing when it expands with heating.

A *safety valve* is the part of a steam-heating system that lets excess steam escape if the pressure becomes too high.

The *water gauge* in a steam-heating system shows how high the water is in the boiler.

An *air vent* is a device on a steam radiator to let the air out so that the steam can come in.

Humidity means the amount of moisture in the air.

A *wet-and-dry-bulb thermometer* shows the amount of humidity in the air by showing a difference or lack of difference in temperature readings between the wet-bulb and the dry-bulb, brought about by differences in rate of evaporation from the wet-bulb according to the amount of moisture in the air.

Brine is a concentrated solution of salt and water used for refrigerating purposes.

ADDITIONAL EXERCISES (P. 304). 4. The water in the pot stays cooler because the pot is porous and allows water to come through to the outside. Here evaporation of the water takes place, and this keeps the remaining water cool.

5. By connecting all the refrigerators with a single compressor by means of pipes, the vapor can all be carried down to one compressor in the basement instead of using a compressor in each refrigerator.

6. The movement of the air in the room takes the warm air away from the condenser pipes.

7. Comparison of refrigerating machine with steam-heating system.

	REFRIGERATING MACHINE	STEAM-HEATING SYSTEM
Where Evaporation Takes Place	In an evaporator.	In the boiler.
Where Condensation Takes Place	In the condenser.	In the radiators.
Coolest Part	The evaporator and just around it.	In the pipes leaving the radiators.
Warmest Part	The compressor.	The boiler.
Source of Energy	Electric motor.	The fuel in the furnace, oil or coal.
How Heat Is Transferred	By conduction and convection.	By conduction, radiation, and convection.

8. The ice gets thicker slowly because: (*a*) the freezing of the first coating of ice produces some heat which warms the water near it, thus making the further freezing take longer.
b) The covering of ice made over the water by the first freezing helps keep heat in and prevents loss of heat necessary for freezing.

9. Salt melts the ice, and a solution of salt water is formed. The addition of salt lowers the freezing point of the solution. The changing of salt from a solid to a liquid takes heat from the solution, as well as the melting of the ice.

10. Experiment on rapidity of conduction of heat by copper and iron. Place one end of a bar of copper, or strip of copper, and one end of a similar piece of iron in a flame and observe in which metal the end away from the flame becomes hot first. A piece of wax can be placed on the end of each bar. The wax will melt first on the bar which is the best conductor.

11. Heat passes from your hand to the ice by radiation, thus making your hand feel cooler.

12. Snow is a poor heat conductor. There is much dead air space in the blocks of snow, and this prevents the loss of heat from the inside of the house to the outside.

13. The water at the top of the tube may boil for quite a long time without the ice at the bottom of the tube melting. This shows that water is a poor conductor of heat.

14. Yes. The aluminum paint would give the top a bright, shiny surface that would reflect the radiant energy of the sun instead of absorbing it. The car would thus be kept cooler.

PAMPHLETS FOR UNIT 6

The Carrier Corporation, 850 Frelinghuysen Ave., Newark, N. J.
  Illustrated Pamphlets on Air-conditioning (free)
The Celotex Corporation, 919 N. Michigan Ave., Chicago, Ill.
  Home Insulating. Well illustrated pamphlet (free)

VISUAL MATERIALS FOR UNIT 6

MOTION PICTURES

Encyclopaedia Britannica Films
  "Hot Air Heating"
  "Refrigeration"
  "Distributing Heat Energy"

FILMSTRIP

Society for Visual Education
  "Fire and Heat"

SAMPLES OF MATERIALS

The Celotex Corporation
  Samples of various kinds of wall-insulating materials

UNIT 7

What Makes the Weather Change?

FUNCTION AND SCOPE OF UNIT 7. Out of the study of this unit should come a reasonable degree of insight into the conditions and processes back of our day-by-day weather and into the work of the Weather Bureau in gathering information and forecasting changes. In addition to the practical importance of such understanding, it helps eliminate superstition and increase the pupils' interest in the processes going on in their surroundings. In the case of a number of pupils, it leads to an interest in keeping weather records and in forecasting the weather for themselves on the basis of observable indications of the location and movements of high- and low-pressure areas.

It is needless to point out to teachers that persons who have a well-rounded education should understand at least something of the scientific principles underlying weather conditions. However, all teachers should bear in mind that hearsay and superstition are deeply rooted in the human mind. These false beliefs are particularly rampant in regard to weather conditions. Consequently, the teacher is urged to show that scientific experiments and methods provide the most accurate explanations of weather changes available and that weather predictions based upon scientific information are of great value to industry, agriculture, travel, and society in general. Examination of the graph on page 175 will clarify the important points to be brought out during the study of the unit.

In this unit, more than in many units, the degree of understanding that can be developed within a reasonable time depends upon pupils' background in science. Previous knowledge or supplementary instruction on the following will be very helpful:

Book 1

Unit 3. The three states of matter.

Units 3 and 4. The molecular explanation of matter.

Unit 4. Changes of state.

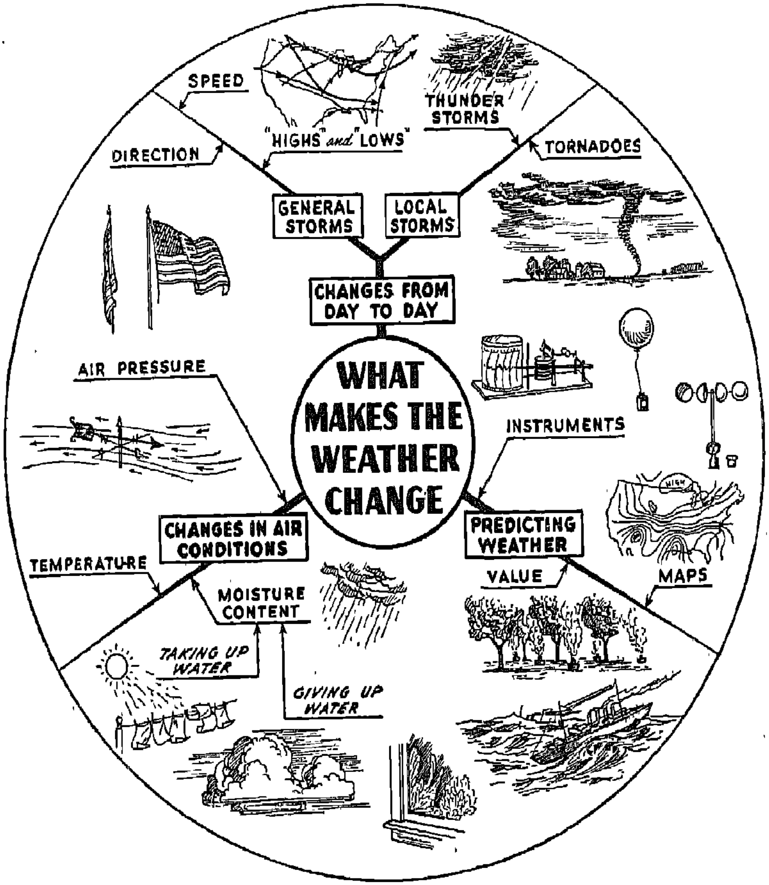

FIG. 14. GRAPH OF THE SUBJECT MATTER OF UNIT 7

Book 2

Unit 2, problem 4.	Air pressure and its measurement.
Unit 4, problem 2.	Convection currents.
Unit 6, problem 1.	Methods of heat transfer.
Unit 6, problem 2.	Humidity and its measurement.

INTRODUCTORY EXERCISES (P. 308). 1. Hot, cold, warm, cool tell about temperature; dry, wet, damp, rainy, snowy, foggy tell about moisture conditions; windy, breezy, still, etc. tell about the air movements.

2. The condition of the sky—whether it is clear or cloudy; the feeling of the air—whether it feels dry or damp; the direction of the wind, etc.

*3. When the temperature falls to the point where it cools the air enough to cause the water vapor to be changed to liquid water.

4. *Wind is moving air. It is really a large convection current,* that extends over a wide region. The air is set in motion by the warming and cooling of different regions of air. This makes the air weigh more per cubic foot in cool places than in warm places. Gravity pulls the more dense air down and along the earth toward and under the warmer air.

5. By contact with the earth's surface, which has absorbed radiant energy from the sun and changed it to heat.

*6. It expands and becomes lighter. It is then pushed up by the denser, cooler air that sinks toward the earth.

*7. Fahrenheit and centigrade.

LOOKING AHEAD TO UNIT 7 (P. 309). Two good ways of handling this material with the class are: (*1*) have the material read before class and have pupils bring a list of weather sayings (pages 310-311) to class, or (2) have the material read in class and make a composite list of the weather sayings that the pupils know.

Begin the lesson by guiding pupils into discussions of weather changes that they have observed. During these discussions make the material vital to the pupils by stressing how these changes have affected *their* lives directly instead of generalizing that weather affects man's activities in various ways. These generalizations should be made by the pupils, but they can be made more profitably later in the unit when pupils have acquired more knowledge and experiences upon which to draw.

The main point of emphasis in this section of the unit should be: (*1*) Weather conditions are very important to all of us, but scientists can do little about the weather except predict its changes a short time in advance. (2) Some ancient weather "sayings" are based on actual observations, while others are merely superstitions.

The teacher will do well to read the classic material relating to weather proverbs and superstitions in W. I. Milham's *Meteorology*, published by the Macmillan Company (1912), in preparing for this introductory lesson.

PROBLEM 1: WHAT CAUSES THE DIFFERENT KINDS OF WEATHER? (P. 312)

This problem should be presented carefully and clearly, because it contains material that is basic to the understanding of the rest of the unit. Since weather at any given time and place is made up of these three factors, (*1*) the way air is moving, (2) the temperature of the air, and (3) the amount of moisture in the air, the entire problem consists of an elaboration of these factors.

A good type of introduction to this problem is the use of pupils' answers to Introductory Exercise 1 (page 308). Words describing the weather may be divided into three groups: (*1*) those that describe movement of air, (2) those that describe the temperature of the air, and (3) those that describe the amount of moisture in the air.

Pupils often have the idea that the air is warmed directly by heat from the sun. Since this is not true, careful presentation of the sub-problem on page 314 should be made. Another common misconception is that warm air has some mysterious tendency to go upward. Actually, warm air goes upward because it is forced up by colder, denser air. (Review of material on page 201 of *Science Problems, Book 1*, and on pages 212-218 and

266-267 of this book may be necessary before attempting to present the sub-problem, "Why Does the Wind Blow?") Other common misconceptions to be avoided are that "frost is frozen dew" and "hail and sleet are the same."

The main ideas of the problem are:

1. Weather is the condition of the air with regard to movement, temperature, and moisture.

2. Air is warmed by contact with the earth's surface, which receives its heat as radiant energy from the sun.

3. Wind is movement of air that results from differences in density caused by temperature (and humidity) differences of two places; winds are parts of huge convection currents in the atmosphere.

4. The moisture in the air is controlled largely by its temperature; warm air can hold more moisture than cool air.

a) Warm air gathers water vapor from moist objects and bodies of water as long as the air is not saturated.

b) Cooling air reduces its capacity to hold water until it finally reaches the saturation point; further cooling causes condensation, the exact form of the condensation depending on surrounding conditions.

1) Dew forms directly from the air on objects that become cooler than their surroundings and cooler than the saturation temperature; under similar conditions but at temperatures below freezing, frost crystals form directly from the vapor in the air.

2) Clouds and fog are composed of enormous numbers of tiny drops of water (or, at low temperatures, of ice crystals) suspended in the air.

3) Continued condensation on cloud particles forms raindrops or snow crystals.

4) If raindrops freeze in falling, they form sleet.

5) If the raindrops freeze and are carried up and down in the violent currents of summer storms, they often receive many layers of ice and fall as hailstones.

SELF-TESTING EXERCISES (P. 314). 1. Because more radiant energy from the sun strikes the thermometer and changes into heat.

2. In a valley there is a much greater expanse of earth's surface to absorb the radiant energy of the sun and warm the air. Also, in a valley the weight of all the air above it keeps the layer of warm air near the earth from escaping as rapidly as it does on the top of a mountain.

SELF-TESTING EXERCISES (P. 317). 1. When the temperature becomes higher, the air is warmed. This makes it expand and become less dense. Conversely, when the air is cooled, it contracts and becomes more dense.

When the air becomes more dense, the pressure of the air is increased because each cubic foot of air weighs more than it did. In the same way, when the air becomes less dense, the pressure is decreased because each cubic foot of air weighs less than it did thus decreasing the total weight of the air.

2. Changes in temperature occur and warm or cool the air. Air warmed by conduction from the earth's surface is pushed up by the denser, colder air. The denser, colder air is warmed and pushed up, and so on. This starts a convection current, and, if the current is large enough, the part of it that is moving parallel to the surface of the earth is known as a wind.

EXPERIMENT 41. IS WATER ALWAYS EVAPORATING INTO THE AIR? (P. 317). The materials and apparatus needed are:

Two wide-mouthed bottles
Cork for one bottle
Gummed labels
Water

Water evaporates from both bottles at first. But the air in the stoppered bottle soon becomes saturated, and evaporation stops. The amount of water evaporated from the stoppered bottle may be too small to observe. Water continues to evaporate from the open bottle until it is all gone.

EXPERIMENT 42. HOW CAN WE MAKE WATER VAPOR CONDENSE? (P. 319). The materials and apparatus needed are:

Tin can (or cup)
Laboratory thermometer
Crushed ice
Water
Salt

This experiment works well under average conditions, but if the air is very dry, salt will have to be added to the water and ice mixture to lower the temperature sufficiently for condensation to take place.

The air about the sides of the cup becomes cooled. The cool air cannot hold as much moisture as it did when it was warmer; thus, moisture is condensed from the air. Have the experiment repeated on different days to show that the dew point varies with the varying humidity.

SELF-TESTING EXERCISES (P. 326). 1. Until the air is saturated, that is, until it holds all the water vapor it can hold.

2. Some of the water vapor in it condenses to liquid water (or to crystals of frost).

3. Warm air. When cold water is poured over a corked bottle of moist air, some of the water vapor in the air in the bottle condenses, because cold air can hold less water vapor than warm air.

4. Saturated air forms dew when it is cooled only a little. Air that is not saturated or is not near the saturation point must be cooled a great deal before condensation occurs.

5. When wind is blowing from a warmer to a cooler place, its capacity to hold water is decreased, and rain may occur. If the air moves upward to a cooler region, the same thing may take place.

When the wind is blowing from a cooler to a warmer place, its capacity to hold water will be increased, and there will be fair weather. When air moves downward to a warmer place, the same is true.

6. *Dew* is formed by the condensation of moisture from air that is cooled below its saturation point.

Frost is formed when the temperature at which the saturation point is reached is below freezing.

Fog is formed when the temperature of a rather thick layer of air falls below the saturation point. The water vapor condenses on dust particles and forms tiny drops of water.

A *cloud* is formed in the air above us in the same way as fog.

Sleet is formed when raindrops fall through a layer of air that is below freezing.

Hail is formed when small bits of ice are formed in the cool air high above the earth. These fall into the warmer air and are covered with water. Air currents carry them up to colder air where the water is frozen to form a layer of ice. This process is repeated until the balls are too heavy to be held up by air currents and fall as hail.

Rain is formed when air is cooled to the point at which it cannot hold all of the moisture it contains. When the particles of moisture come together and form drops too heavy to stay in the cloud, they fall as rain.

PROBLEMS TO SOLVE (P. 327). 1. No. They merely condense from the air directly on objects near the surface of the earth.

2. Refer pupils to Science Readings for Unit 7, page 552 of the textbook.

3. On cold days our warm breath is cooled. Since it can then hold less moisture, some of the moisture condenses into tiny droplets that we see as our "breath."

4. Clouds help prevent radiation of heat from earth and air. Earth and air do not cool below the freezing point and thus no frost is formed.

5. Warm air can hold more water vapor than cold air.

6. The iceberg sticking up into the air cools the air near the iceberg, so that water vapor in the air condenses and forms a fog.

7. Air warmed by sun can hold more water vapor, therefore fog evaporates into the air.

8. As warm, moist wind blows up from the ocean to the mountains, it is cooled until much moisture falls as rain or snow. Because the wind has little moisture left to condense, it causes a desert on the other side. Also as air descends on other side it is warmed and takes up moisture.

PROBLEM 2: WHY DOES THE WEATHER CHANGE FROM DAY TO DAY? (P. 328)

Since the pupils have studied in Problem 1 the factors that make up the weather at any given time, this problem builds upon the knowledge of these factors to show how their interactions with each other cause the weather to change.

Intelligent understanding of weather changes is based upon an understanding of high- and low-pressure areas, the conditions that accompany these areas, and the general paths that these areas follow in their movement across the continent. Consequently, the emphasis of the teaching should be toward understanding and interpreting the movement of these areas in relationship to everyday weather changes. Modification of the general behavior of "highs" and "lows" due to local topographic conditions should be pointed out.

It is assumed that the teacher will have subscribed for weather maps well before the beginning of this unit and that these have been posted and used from day to day as the unit is developed. If maps are available and they have not been explained earlier, time should be taken at the beginning of this problem to teach pupils how to read weather maps.

(Note: Since the publication of *Science Problems, Book 2* the United States Weather Bureau has begun the introduction of a new series of symbols and other changes in the weather maps. If the maps in use do not agree with those shown in the textbook, an adequate key will be found on the maps themselves or can be obtained by writing to the Weather Bureau.) Readings and use of data from these daily maps should continue during the entire problem. The main ideas to be emphasized are:

1. Changes of weather usually occur as a result of the movement of high-pressure areas and low-pressure areas.

a) "Lows" bring humid weather with clouds, and often rainfall, because the air is moving toward the center from all directions and there is forced upward and cooled.

b) "Highs" bring clear, cool, dry weather because the air in the center is moving downward. The air is warmed and can take up more water vapor.

c) The general movement of these areas is from west to east across the United States; the most-frequently followed paths have been carefully charted by weather experts.

2. The local storms of summer are miniature low-pressure areas that drift with the prevailing winds. Electrical discharges often accompany local storms.

3. Tornadoes are violent whirling storms that sometimes occur when very warm masses of air meet colder masses of air.

a) These storms are usually confined to the central and southeastern parts of the United States and occur in the spring.
b) Tornadoes over bodies of water are known as waterspouts.

SELF-TESTING EXERCISES (P. 333). 1. (a) The meaning of the different symbols: arrows, circles, etc.
b) The meaning of the solid lines and numbers on them (isobars).
c) The meaning of the dotted lines (isotherms).
d) The meaning of "high" and "low."
e) How the numbers for pressure and temperature are obtained.

2. Cloudy, rain (or snow) and warmer. Air-pressure is less in the center of a "low" because the air there is warmer than the surrounding air. Air is pushed upward in center and cooled. As it cools, condensation, forming clouds, rain, or snow, takes place.

3. Fair, little or no rainfall, cool. Air pressure is greater in center, and cool air descends. As it gets nearer the earth, the air is warmed and evaporation from the earth occurs. Thus it is cooler, and there are no clouds or precipitation.

4. In northwest and southwest. To east and northeast; some to southeast.

5. Southeast.

SELF-TESTING EXERCISES (P. 337). 2. Rapidly rising air currents.

3. Because the temperature differences between the bottom and the top of a cloud are very great, and the upward rush of the current carries moisture very high to a point where it freezes and forms hail.

4. In the late spring, summer, and early fall when the land is warmed most by the sun, and, therefore, the air above the heated land is heated most and is forced upward.

PROBLEMS TO SOLVE (P. 338). 1. Refer pupils to Science Readings for Unit 7, page 552.

Some ways in which these storms are alike are: (a) They are the most violent wind movements known.
b) They occur when weather is hot and moist.
c) The air moves in a great "whirlpool" and at the same time moves forward in an easterly or a northeasterly direction.
d) Hurricane and typhoon are two names for one kind of tropical cyclone.

2. Refer to Science Readings on page 552.

PROBLEM 3: HOW ARE WEATHER FORECASTS MADE? (P. 338)

The work of collecting meteorological data engages the services of many people in practically every civilized country. In the United States this work is carried on almost entirely by governmental agencies. The results of their work are presented daily in the form of maps which give a picture of weather conditions over the entire country.

The study of essential instruments that are used by meteorologists and the way in which data collected by these people are used in making forecasts affords a splendid opportunity for showing that weather forecasting is a scientific business. People everywhere complain when meteorologists "miss" on their predictions; so a good word from the teacher in favor of forecasters is in order during the study of this problem. It should be recognized by the pupils that in spite of the extremely rapid changes in atmospheric conditions, the "weather-men" on an average throughout the country are accurate over eighty-five per cent of the time. This can be shown most convincingly if all members of the class will do Problem to Solve 5, on page 349. This concluding problem of the unit affords a splendid opportunity for showing relationships between science and everyday living, since so many of our important activities are directly related to a knowledge of immediately impending weather conditions.

The main ideas to be stressed are:

1. Weather conditions all over the country are observed and measured with the aid of carefully designed instruments, many of which keep continuous records automatically; conditions high in the air are discovered with the help of small balloons, some of them carrying instruments.
2. In the forecast centers of the United States Weather Bureau, information from hundreds of observers is used to make up weather maps that show the country's weather at a glance.
3. Forecasters study these maps, predict the movements of the "highs" and "lows" and, from this and other information, make up the daily forecasts on which we depend.

4. The work of the United States Weather Bureau is of untold value to those whose work and prosperity are directly and indirectly dependent on weather conditions.

SELF-TESTING EXERCISE (P. 342). Weather forecasters get these kinds of information:

Kinds of Information	*Instruments Used to Get It*
1) Atmospheric pressure	Barometer
2) Humidity	Wet-and-dry-bulb thermometer
3) Temperature	Thermometer
4) Direction of wind	Wind vane
5) Speed of wind	Anemometer
6) Amount of rainfall	Rain gauge

SELF-TESTING EXERCISES (P. 347). 2. You would predict northeast wind, increasing cloudiness and then rain. These conditions would occur first in Oklahoma City, later in Kansas City and still later in Chicago because in all probability, the "low" would move north-eastward.

3. If you face the "low" the wind will usually blow from behind you and somewhat from your left. Thus, if the "low" is west of your city the wind will usually be from the east or southeast.

4. When the barometer falls, the change of wind is due to the approach of a "low." When it rises, the wind change shows the approach of a "high."

5. A weather map locates the positions of the "highs" and "lows." On the basis of the records collected over years, he can predict what "highs" and "lows" in these positions probably will do.

6. No. Even if one can predict what probably will happen on the basis of records collected over a long period of time, local changes in conditions may arise that change the behavior of the weather. Furthermore, since it takes only about four days for one "low" or "high" to travel across the continent, it is not safe to predict what "lows" and "highs" will be present several weeks in advance. (Note: Some fairly accurate longer range weather forecasting is now being done by scientists but is not available to the general public. Thus the "No" in this answer should not be too emphatically maintained.

However the distinction between these long-range predictions and those of advertising calendars should be clearly brought out.)

7. Yes. Because of the number of lives and amount of property it saves in predicting storms for the benefit of shippers, aviators, motorists, people living on the coasts, farmers and grove owners, etc.

PROBLEMS TO SOLVE (P. 348). 4. Smudge fires protect orchards from frost by creating an artificial cloud of smoke that helps prevent the loss of heat from the ground by radiation. The cloud tends to hold the heat in. The heat of the fires also helps raise the temperature of the surrounding air.

LOOKING BACK AT UNIT 7 (P. 349). 1. (a) Direction and speed of the wind; (*b*) pressure of the air; (*c*) temperature; (*d*) condition of sky (clear, cloudy, partly cloudy); (*e*) amount of moisture; (*f*) kinds of precipitation (rain, snow, fog).

2. (a) I would need to know that the symbols on the weather map tell what the weather is like all over the country and what each symbol and line means.

b) I would need to know that a "high" brings cooler clear weather with wind moving outward in a clockwise spiral direction and that a "low" brings the opposite.

c) I would need to know that "highs" and "lows" move in a general easterly direction with certain special paths depending on where they start; that they take about four days to cross the country.

3. *Radiant energy* is energy in the form of invisible rays, which travel in straight lines, from some heated source, such as the sun.

Water vapor is water in the form of gas that is mixed with the air.

Saturated air is air that contains all the water vapor it can hold.

Hail is the kind of precipitation formed when small bits of ice are formed in the cool air high above the earth. These fall into the warm air and are covered with water. Air currents carry them up to colder air where the water is frozen to form a layer of ice. This process is repeated until the balls are too heavy to be held up by air currents.

A "*high*" is the high-pressure area that brings clear, cool, dry weather because the air in its center is moving downward, where it will be warmed and take up more water vapor.

A *tornado* is a violent whirling storm that moves forward as a funnel-shaped cloud with the top touching the ground.

A *thermograph* is an instrument for measuring and recording the temperature continuously for a week or more.

Sleet is the form of precipitation that results when raindrops fall through a layer of cold air and are frozen.

A *"low"* is the low-pressure area that brings cloudy, warm, and rainy weather because the air is moving in toward the center from all directions and is forced upward and cooled.

A *waterspout* is the name given to a tornado over an ocean or sea.

A *barograph* is an instrument that measures and records the air-pressure continuously for a week or so.

Frost is the form of precipitation that results when frost crystals form directly from vapor in the air on objects below freezing.

Humidity means the amount of water vapor in the air.

Cirrus clouds are the highest clouds in the sky. They are made of tiny ice crystals and always look white and feather-like.

An *anemometer* records how hard the wind is blowing.

Wind is air in motion—really a large convection current set in motion by the warming and cooling of different regions of air.

ADDITIONAL EXERCISES (P. 350). 2. Briefly, layers of air with great differences of temperature (one layer usually very hot) cause rays of light from object to be bent. They may appear high in sky and present a distorted image of object.

4. In zigzag lightning the actual path of the electrical discharge is visible, but in sheet lightning we see the illumination of a cloud by a discharge whose actual path is not visible.

PAMPHLETS AND BULLETINS FOR UNIT 7

Taylor Instrument Company, 95 Ames St., Rochester, N. Y.
Weather Series for the Amateur. 15c
Weather. Book of 144 pages, fully illustrated. $1.00

United States Department of Agriculture
Weather Bureau. Bulletin 42. *Weather Forecasting.* 10c
Farmers' Bulletin 1588. *Frost and Prevention of Frost Damage.* 5c

VISUAL MATERIAL

MOTION PICTURE

Encyclopaedia Britannica Film. "Weather Forecasting"

CHART

United States Department of Agriculture. Weather Bureau.
Cloud Forms. 1 sheet. 12 illustrations. 5c

UNIT 8

How Do Our Bodies Work?

FUNCTION AND SCOPE OF UNIT 8. Early health habits must be established before the reasons for them can be understood by the child. Later on, children want to know the why of health practices that are constantly insisted on and they want to know how their bodies work. A real understanding of the body's main features of structure and function provides an intelligent attitude both for everyday health and for emergencies as well as for the pupils' thought about the human body.

The emphasis of Unit 8 is on understanding of the body's functions and the structures that enables it to carry out those functions. There is also an emphasis on appreciation of the fitness of structure to function, yet in connection with each main function, the significant health implications are clearly pointed out. See the graph for this unit on page 189.

The teacher should vary the emphasis on health practices to fit the needs of the class. In groups which have a good foundation in health instruction from the home and earlier grade instruction, the text may be followed very much as it is. Other groups, for whom earlier instruction or habit formation has been neglected, should however consider at length the health habits that are essential at this age. The starting point should be understanding of function. Then the question should be raised, "How can we best keep our body working properly in this respect?"

Most units based on the body ignore completely the function of reproduction. This omission only increases the curiosity of boys and girls about reproduction and sex. It has seemed best in this unit merely to mention the reproductive system and to defer consideration of its function to Unit 10, when pupils will have a background of the general process of reproduction among living things.

Many ideas from earlier units will be helpful in the study of this unit, although the teacher can effectively supplement the text in case the class has not studied all the earlier units.

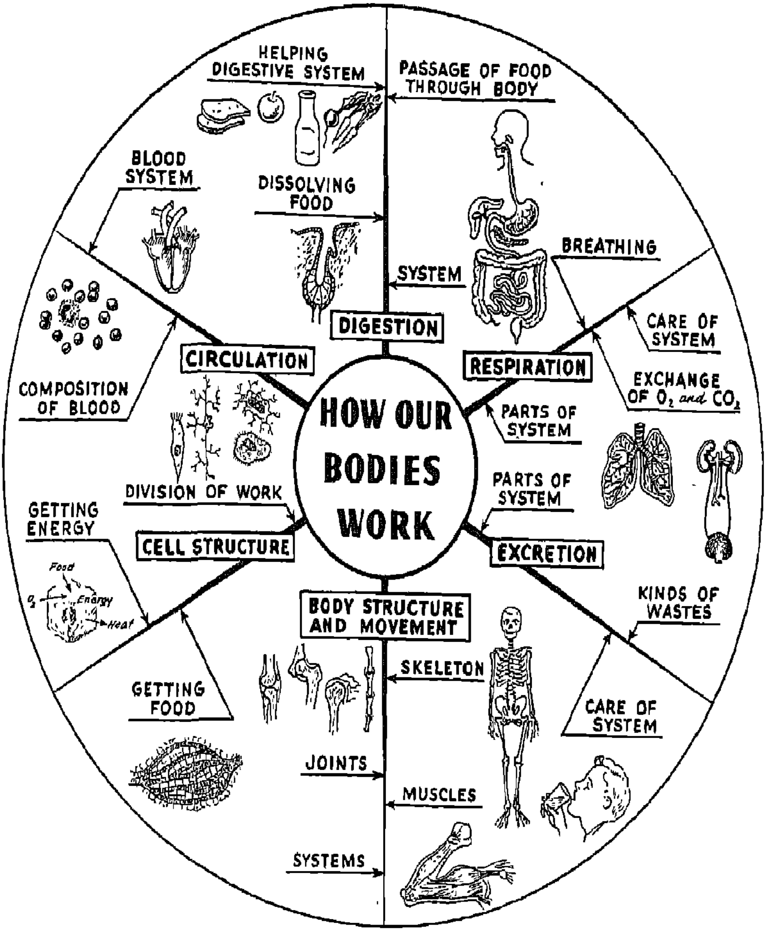

FIG. 15. GRAPH OF THE SUBJECT MATTER OF UNIT 8

Book 1

Unit 3. All materials seem to be made of tiny particles called molecules. In liquids, gases, and dissolved solids individual molecules are relatively free from each other and can move about by a kind of bouncing motion.

Unit 5. Materials change chemically by undergoing rearrangements of their elements in compounds.

Units 6 and 10. Oxidation of foods and fuel releases the stored energy they contain. Oxidation of compounds containing carbon produces carbon dioxide, a gaseous compound of carbon and oxygen.

Unit 8. All living things are made of elements and compounds; among these oxygen, carbon, hydrogen, and nitrogen are most abundant. All living things contain cells in which the living material is protoplasm; these cells carry on all the activities of living things.

Unit 9. Animals, including man, depend on green plants for their food supply. Green plants, with the aid of light energy, manufacture foods from carbon dioxide and water. Plants such as bacteria must get their food from other plants or animals.

Unit 10. Food provides the energy and building materials for our bodies. Minerals, vitamins, and water as well as carbohydrates, fats, and proteins are needed to keep our bodies healthy.

Book 2

Unit 5. Energy is what causes all changes and actions. Energy changes from one form to another without being destroyed or created. Energy in foods is in the form of chemically stored, or chemical potential, energy. It can be changed into heat and kinetic energy by a chemical change in the food.

The understanding of the body developed in Unit 8 will be helpful in the study of Unit 9, "How Can You Help Your Body Fight Disease?"

INTRODUCTORY EXERCISES (P. 352). *1. Cells of living things are the small divisions of protoplasm that make up each plant and animal. Cells are found in every part of the body, since they make up almost the whole body and carry on all its activities.

2. Bones support the body and give it shape; bones protect some of the softer parts of the body; bones help you move because they act as levers to help pull or push you about.

*3. (a) *Oxidation of fat and carbohydrates.* Gives heat and energy.

b) *Digestion of foods.* Gets materials into forms that can dissolve and be used by body.

c) *Combination of foods into protoplasm.* Growth and repair of the body.

4. Mouth, esophagus, stomach, small intestine.

5. Three kinds: the capillaries, the arteries, and the veins. The capillaries are tiny, thin-walled tubes. The arteries are larger tubes through which the blood passes from the heart into the capillaries. The veins are tubes that carry the blood back to the heart.

6. Foods must be digested to make them soluble, so that they can pass through the cells lining the intestine and get into the blood. (Some soluble foods must be changed into slightly different substances that the body can use.)

*7. It needs heat energy and the energy of motion (kinetic energy). It gets the energy it uses by oxidizing food materials in the cells.

8. Because the flow of blood stops and the cells no longer receive oxygen and food. Without food and oxygen the cells all over the body quickly die.

9. Air is necessary because the oxygen to oxidize the food in our cells comes from the air.

10. The kidneys remove certain kinds of wastes from the blood and help regulate the amount of water and other materials in blood.

*11. When a solid is dissolved, it is broken up into very small particles. These particles are scattered evenly throughout the liquid in which the solid is dissolved. The liquid plus the particles of the solid is known as a solution. *Soluble* means that a solid is capable of forming a solution.

*12. Oxidation is a chemical change in which oxygen combines with some other material.

*13. The three main classes of food are: (a) *carbohydrates*, containing carbon, hydrogen, and oxygen; (b) *fats*, containing carbon, hydrogen, and oxygen; (c) *proteins*, containing carbon, hydrogen, oxygen, and nitrogen, and sometimes phosphorus and sulfur.

LOOKING AHEAD TO UNIT 8 (P. 353). This is one unit for which most classes of boys and girls can almost make up their own previews. Ask the class the questions, "What would you like to know about the body?" "What things about your own body have puzzled you?" Have a number or all of the "puzzles" stated orally and written on the blackboard. Then ask the pupils, "Do you think an educated person should know how the body works? Why?" and let the class do the talking. If the discussion is successful, the preview in the text may be omitted—most pupils will read it anyhow—and the class may go right on to planning its work on the unit.

If the pupils' "puzzles" are still on the blackboard, they may be classified to find the divisions of study to be taken up. Or the pupils may be asked to list the divisions of the unit that should be made and to decide which should be taken up first. However, if this plan is followed, the teacher should be careful to let the class go through with the plan of study it has laid out, even though it requires much study of other books and neglect of the order of development in the text. The results will more than pay for the trouble.

Many teachers may prefer to give an introductory talk or to have the text preview read and then go on to the study material as it is arranged in the text. The main ideas developed in the printed preview are:

1. To be intelligent in the use of a machine such as an automobile, we need to know how it works and how to operate it most wisely.
2. The human body is a complicated and wonderful thing that each of us should understand reasonably well in order to care for it as well as possible.
3. The material presented in this unit is only a foundation for learning all through life and will help you understand some of your later work in science.

PROBLEM 1: HOW IS YOUR BODY PUT TOGETHER? (P. 355)

When we first become familiar with anything, such as a house, a machine, or a city, in a natural way, the first ideas we obtain are general—the floor plan of the house, the general use and method of operation of the machine, the general plan of the city. This problem serves to lay out the general "floor plan" and structural plan of the human body before going into detail about its essential functions. Details should be grasped—the teacher and pupils may wish to add many more from other sources—but the purpose of the problem will have been missed if the pupil completes his study without a mental image of the main parts of the body in their structural relations to one another.

This mental picture should include the following main ideas:

1. The body's framework, composed of bone and cartilage, supports and protects other parts and assists in moving.
2. The entire skeleton is built about the backbone as an axis.
3. The movable joints between bones are well-constructed and well-oiled bearings held together by tough ligaments.
4. Muscles do a difficult job in balancing and moving the entire body. They can only contract and so must usually work in opposing pairs.
5. A muscle has a mass of contracting tissue composed of "lean meat" connected to bones by tough white tendons.
6. In spaces of the skull, back bone, thorax, and abdomen lie the main parts of the different systems necessary to run the body: the food system, the breathing system, the blood-circulating system, the kidney system, and the nervous system.

SELF-TESTING EXERCISES (P. 356). 1. The main divisions of the body's framework: backbone, skull, shoulder girdle, hip girdle, bones of thorax (breastbone and ribs), bones of arms and legs. (This answer should be based mainly on Figure 271, page 356.)

2. Advantages of cartilage: (a) Makes it possible to have body parts that have shape and yet are flexible, such as the nose and ears. *b*) Pads of cartilage help lessen jar on backbone when we walk.

c) Cartilage makes a smooth, hard bearing in joints. (This point is not brought out until later, but pupils may include it here.)

3. Three important uses of the skeleton: (*a*) it supports and gives shape to the body; (*b*) it makes more effective motion possible; (*c*) protects certain soft and delicate parts of the body.

EXPERIMENT 43. WHAT IS THE STRUCTURE OF A JOINT? (P. 357). The apparatus and materials needed for each demonstration or group of pupils working together are:

- One sheep shank (or other uncut joint from a butcher shop)
- One sharp knife or scalpel (A pair of short, sharp dissecting scissors is very useful.)
- Impervious wrapping paper, or tray or board on which to work

In most communities the members of the class can help collect suitable material for this exercise. The result is usually a variety of joints—hinge and ball-and-socket, from chicken leg to beef shank. If a number of sheep or lamb shanks are ordered, be sure the butcher does not cut them right through the joint and thus ruin them for the exercise.

Many pupils will tend to work too rapidly on this dissection and will miss much that is to be gained by doing it. Variations can be made to avoid superficial work. The teacher may prepare a demonstration specimen before class and show the pupils what each part looks like before setting the class to work. Or, in city schools each interested pupil can obtain a specimen from his neighborhood butcher, study it at home, and bring it carefully wrapped to show the class what he has discovered. A series of exhibits can thus be set up with the pupils moving from one exhibit to another. With any saw the different kinds of bones may be cut crosswise and lengthwise to see how they are constructed. All material should be kept under refrigeration if it is to be used for more than one day.

It is often best to make the actual study of muscles (Experiment 44) at the same time as that of joints and bones and thus save the trouble of repeated calls for material. Much of the material for Experiment 43 will have whole muscles or parts of muscles attached and these can be examined with profit.

Self-Testing Exercises (p. 359). 1. Good points about the way our joints are constructed (three required): (a) The ends of the bones fit together perfectly.
b) The ends of the bones are enlarged for strength.
c) The ends of the bones are covered with smooth, flexible cartilage.
d) They have ligaments that keep the bones from being pulled apart or moving in the wrong direction.
e) The joints are lubricated to help them move smoothly.
f) The joints are lined with sacks to keep foreign material out and lubricating material in.

2. The main use of the ligaments is to keep the bones from being pulled apart or from moving in the wrong direction.

3. Hinge joints and ball-and-socket joints. The hinge joint enables the bone to move back and forth in only one direction (plane), while the ball-and-socket joint enables the bone to move and twist in all directions.

4. A sprain occurs when the ligaments are stretched too far, and a joint becomes sore and stiff. A dislocation occurs when the bones are pulled out of their proper place.

5. To prevent the broken ends of the bone from grinding against one another, and possibly tearing the flesh.

Experiment 44. What Is the Nature of Muscles? (p. 361). The apparatus and materials needed will vary a great deal with the way in which the observations are carried out. If all observations are made in the classroom, the following should be available:

Leg of some fowl or meat animal that includes one or more muscles with both ends still attached to tendons and bones
Pieces of boiled lean beef
Dissecting needles or darning needles. (Two are needed to pull the fibers apart.)
Magnifiers and a compound microscope with glass slides

Pupils may be encouraged to make many observations on muscles in many different ways and many different places. Probably too much observation at the dinner table is not wise. However, many pupils do not know that lean meat is muscles, and direct observation should be carried far enough to make the connection real. Once an entire muscle has been seen attached to bone at both ends, pupils can trace their own muscles from attachment to attachment by feeling them beneath the skin.

In pulling apart the cooked beef, pupils should see the fine fibers of the connective tissue that hold the muscle fibers together and which are softened by cooking. Blood vessels may often be seen in the material being examined in this exercise.

SELF-TESTING EXERCISES (P. 362). 1. The paragraph describing the muscle should include (*a*) color, (*b*) shape, (*c*) tendons, (*d*) finer structure.

2. The tendons connect the muscle to bones. The description of tendons should include (*a*) color, (*b*) shape, (*c*) strength.

3. The muscles are remarkable because: (a) They can become longer or shorter as required.

b) A great number of them work together to make each movement. This means that a great deal of coördination is required.

SELF-TESTING EXERCISES (P. 364). 1. This exercise can be neatly arranged in the form of a table of two columns. Sets of organs in the body: (a) The skeletal system—gives the body shape and protects soft tissues.

b) Muscular system—supports and moves skeleton and other parts.
c) Respiratory system—supplies the body with oxygen (breathing).
d) Digestive system—prepares food for use in the body.
e) Urinary system—takes certain wastes from the blood.
f) Reproductive system—produces new bodies.
g) Circulatory system—carries the blood throughout the body.
h) Nervous system—controls the activities of the other systems.

2. The two cavities: (a) Chest cavity or thorax: contains lungs and heart.

b) Abdomen: contains liver, stomach, intestines, etc.

PROBLEMS TO SOLVE (P. 364). 1. (a) Hinge joints in the body: knee, fingers, elbow, toes (at least sixty).

b) Ball-and-socket joints: shoulder, hip.

(Note: Questions may be raised about wrists, ankles, neck. These are neither simple type and really involve two or more joints working together. Pupils may wish to look up the details in reference books. The elbow is not a simple hinge joint.)

2. *Ways in which a joint is like a bearing*	*Ways in which a joint differs from a bearing*
1) It allows free motion between two stiff parts.	1) Differ in shape.
2) It is lubricated.	2) Machine bearings can't repair and lubricate themselves.
3) Lined with smooth material.	3) Joints cannot allow completely free rotating motion such as occurs in machines.
4) Covering to keep oil in and other materials out.	

3. Reasons for believing the blood system extends all through the body: (a) An injury, such as a cut, in any part of the body will bleed, showing that blood goes to all parts of the body.

b) In many parts of the body the veins that form part of the blood system are visible at the surface of the body.

c) Cells throughout the body carry on oxidation, and since they must receive their oxygen and food from the blood and give back used materials to it, the blood must be carried throughout the body.

4. Reasons for believing that the nerve system extends to all parts of the body: (a) We feel pain and other sensations from all parts of our bodies, and this indicates the presence of nerves to transmit these messages to the brain.

b) It is the controlling system; and since all parts of our bodies are active and respond to stimuli, it seems probable that nerves extend to all parts of the body.

PROBLEM 2: HOW DO OUR CELLS KEEP ALIVE? (P. 365)

The work of the digestive, respiratory, circulatory, and kidney systems is really intelligible only if seen in connection with the activities of the living tissues all over the body. The study of Problem 2 should result in a clear mental picture of the requirements of the individual cells and the method by which materials move into and out of the cells. The main ideas developed are:

1. Living cells in all parts of the body carry on all the body's activities.

2. Energy for the activity of each living cell is obtained by combining food with oxygen; by this change the chemical energy of the food is converted into heat and motion.

3. Carbon dioxide and nitrogen wastes are produced by the chemical changes of cells and must leave the cells.

4. Dissolved materials (food, oxygen, and wastes) move into and out of cells by the migration of the separate molecules through the cellular substance.

5. Blood flowing near each cell brings new materials close enough to each cell so that they can diffuse in and carries away used materials after they have diffused out.

6. The cells of the body are organized into the different systems, each one of which does some special thing for all the other living cells in the body.

EXPERIMENT 45. WHERE AND IN WHAT FORM DOES USED CARBON LEAVE THE BODY? (P. 366). The apparatus and materials needed are:

Beaker or clean glass tumbler	Limewater (from drug store, or supply house)
Soda straw or glass tube	

In doing the experiment the breath from the mouth and air passages should be blown out before bubbling some from the lungs through the limewater. This plan produces results more quickly. The limewater invariably turns milky.

The answer to the problem is, of course, that the used carbon leaves the body through the lungs in the form of the invisible gas, carbon dioxide (CO_2), a compound of carbon and oxygen.

SELF-TESTING EXERCISES (P. 367). 1. Food and oxygen are carried to the cells in the blood stream. They go into the cell and there the two are combined (the food is oxidized). During the process of oxidation chemical energy in the food is changed to the kinds of energy that the cell can use.

2. Carbon dioxide is formed in the cells all over the body by oxygen combining with carbon in food materials.

3. It showed that the carbon dioxide formed in our cells leaves the body through our lungs.

EXPERIMENT 46. HOW DOES ONE MATERIAL MOVE THROUGH ANOTHER? (P. 368). The apparatus and materials needed are:

Beaker or tin cup	Source of heat

At least one test-tube (the jelly mixture fills three)
Four grams of agar-agar in shreds or granular form
100 cubic centimeters of water ($\frac{1}{5}$ pint)
Support for test-tube in vertical position (glass tumbler or jar may be used)
Glass container for ink (the beaker used for making the jelly can be used)

The tube (or tubes) of jelly should be prepared before the class meeting at which it is first to be used. If prepared several days in advance, it may be kept indefinitely by inverting it in a container of clear water.

A noticeable amount of diffusion occurs in a few minutes. However, the rate of movement slows down so much that weeks or months are required for the color to reach the closed end of the tube.

An illuminating supplementary experiment that illustrates the necessity for materials to be in a soluble form for diffusion, may be carried out at the same time. Use a second test-tube of jelly inverted in a vessel of water mixed with powdered "ball-blue" (bluing in the form of a small ball usually obtainable from grocery stores). The "ball-blue" is insoluble and does not color the jelly at all.

SELF-TESTING EXERCISES (P. 371). 1. Food and oxygen are in solution in the blood and move into the cells from the blood stream by diffusion.

2. It must be dissolved.

3. Capillaries are very small, thin-walled blood tubes that are found everywhere among the cells of the body.

4. It is important because the blood flowing through the capillaries brings near the cells the materials they need and carries away waste materials from them.

5. The cells of the body are not all alike. They are of different sizes and shapes and perform different duties in the different organs of the body. Each type of cell does one kind of work for all the other cells of the body. Thus the cells in the digestive organs help prepare food for all the other cells and the cells of the circulatory system send blood to all the other cells. This is called division of labor.

PROBLEMS TO SOLVE (P. 371). 1. The body and a locomotive.

Ways the body is like a locomotive	*Ways the body differs from a locomotive*
a) It needs fuel for energy.	a) The food must be digested and changed before it can be used as fuel by the cells.
b) Energy is obtained from the fuel by oxidation.	b) The body can use its "fuel" for making new cells and other materials needed by the body, as well as for energy.
c) Oxygen is obtained from the air for use in oxidation.	c) The temperature of oxidation is much lower in body.
d) It gives off waste products including carbon dioxide.	d) Oxidation in the body occurs everywhere in the body, while in the locomotive it is confined to one space.
e) It produces heat and kinetic energy.	
f) It needs much water.	
g) It has different "systems" to keep it going.	
h) Has well-lubricated joints.	
(Many other similarities may be found.)	(Many other differences may be found.)

2. (a) Some sugar is in the blood in a capillary.

b) From the thin-walled capillary the sugar diffuses into the cell through the cell membrane.

c) In the cell the sugar unites with oxygen. From this oxidation the cell obtains some energy. The carbon of the sugar unites with oxygen and forms carbon dioxide. The carbon dioxide diffuses out of the cell into the blood.

3. Most living things die when they are unable to obtain oxygen, because union of oxygen with food is needed to provide the energy necessary for carrying on life activities. When the cells fail to get this energy from food uniting with oxygen, they quickly die.

4. Examples of diffusion outside the bodies of living things:

a) Gas from an unlighted gas burner spreads throughout a room by diffusion.

b) Moth ball material spreads from moth balls all through a trunk and out through the cracks where one may smell it.

c) Perfume diffuses out around the stopper of a bottle.

d) Sugar is dissolved in a cup of tea and the molecules spread throughout the cup by diffusion (if it is allowed to stand without stirring for a long time).

c) A rubber balloon filled with hydrogen gradually shrinks because the hydrogen diffuses out through the rubber.

(Other examples will be found.)

5. Food and oxygen do not need to be carried so far to reach all the cells, as they do in larger animals. In the smallest animals where there are only a few cells, or only one, food and oxygen can diffuse into all parts of the animal as rapidly as they are needed.

6. (a) The cells of our bodies are like the people of a city in that there is division of labor among them. Some types of cells are fitted to do one thing and others, another. But the activities of each kind are for the benefit of the whole body.

b) They are different in that they could not go on living without the activities of the other cells. People, however, could go on living without the others, although in a great city this would be difficult.

PROBLEM 3: HOW DOES BLOOD MOVE THROUGH YOUR BODY? (P. 371)

The study of Problem 2 has already made clear the place of the blood as a carrier of materials. As yet most pupils will have only a confused idea of the real arrangement of the blood vessels and the way in which the heart works. The purpose of the study of this problem is, therefore, to gain a clear mental picture of the circulatory action as a whole.

The main ideas needed to solve the problem are:

1. Blood is essential to the work of the body because it carries materials from one part of the body to another.

2. Branching arteries, leading from the heart, capillaries passing among the cells, and veins leading back to the heart form a closed path through which the blood flows around and around.

3. The blood is a clear liquid in which float myriads of red corpuscles, the oxygen carriers, and white corpuscles, which are germ fighters.

4. The heart is a hollow muscular organ; when the heart muscle contracts, the blood in it is forced out into the arteries;

valves in the heart and in the mouths of the arteries force the blood always to flow in an outward direction.

5. The heart is divided by a solid partition into two sides; one side receives blood from all parts of the body and pumps it through a large artery to the lungs and the other side receives blood from the lungs and pumps it through one large artery into all the other parts of the body.

6. A good healthy way of living, with proper medical advice, helps to keep the circulatory system in working condition as long as possible.

EXPERIMENT 47. WHAT IS THE APPEARANCE OF BLOOD UNDER A MICROSCOPE? (P. 373). The apparatus and materials needed are:

Compound microscope
Slide and cover glass
Clean, new needle
Ethyl alcohol, 80% or more

Be sure not to add water to the blood used for examination. The drop of blood used should be large enough to fill much of the space beneath the cover slip but small enough to spread out very thin. To have a natural appearance, it must be examined with reasonable promptness after the slide is prepared.

(Note: To prepare 80% alcohol add 15 cc. water to 80 cc. of 95% alcohol.)

Desirable demonstrations. 1. If possible, obtain a sheep's heart or a beef heart from a butcher. Usually, if ordered in advance, they can be obtained with the receiving chambers and some of the blood vessels still attached. For a probe use a two-foot length of fairly stiff copper wire doubled in the middle to form a smooth end. Flaps may be cut in both sides to examine the interior of the heart and see the valves. The pumping chamber with the thinner wall is the right side and sends blood to the lungs. Unless he is quite familiar with the anatomy of the heart, the teacher should trim away the membranes about the heart and locate its important features before attempting to demonstrate them to a class.

2. A small goldfish can be used to demonstrate the circulation of blood through the blood vessels. Use the smallest fish available. Put it in one-half pint of water with a tablespoonful of saturated solution of chloretone. As soon as the fish stops swimming and comes to the top, lift it out with wet fingers and wrap the whole fish except the tail in a thin layer of wet cotton. Lay the wrapped fish on one end of a microscope slide with the tail spread out on the other end. Wrap a small cord about the cotton-covered fish to prevent its flopping off. Drop water on a thin part of the tail and lay a cover slip on the water. Place the whole preparation on the stage of a compound microscope. Through the low power, the blood can usually be seen flowing out into the tail in arteries, passing through narrow capillaries, and returning to the body through veins. After twenty or thirty minutes the fish can be returned to pure water and will usually revive uninjured. (For further details about such an experiment see the *American Biology Teacher*, Feb. 1940, p. 128.)

SELF-TESTING EXERCISES (P. 378). 1. The important parts of the circulatory system: (a) The blood—carries materials from place to place in the body.
b) The heart—pumps the blood and makes it flow.
c) Arteries—carry the blood from the heart.
d) Capillaries—small blood tubes that bring the blood in close touch with all the cells; connect smallest arteries with the smallest veins.
e) Veins—tubes that lead the blood back to the heart.

2. Parts of the blood noticed under the microscope: (a) Red blood cells—have hemoglobin and carry oxygen and carbon dioxide.
b) White corpuscles—help fight disease germs.
c) Liquid part—contains salt and many different substances needed by body; carries dissolved food to cells in all parts of body and carbon dioxide away from the cells.

3. The heart pumps blood by means of its contractions. When the muscles contract, they squeeze blood out of the heart. When they relax, the blood flows into the heart. The valves between the receiving chambers and the pumping chambers prevent the blood from flowing backward.

4. The heart is divided into two parts so that from one side blood that contains oxygen is pumped to all parts of the body, and from the other side, blood containing carbon dioxide is pumped to the lungs.

PROBLEMS TO SOLVE (P. 378). 1. After strenuous exercise; when you are excited for some reason.

2. The pulse can be felt in the wrists, at base of neck, in front of the ear, and various other places.

3. Clear directions for stopping dangerous bleeding from a cut may be found in any good first-aid book such as: *The American Red Cross Textbook on First Aid and* Relief Columns; Cole, N. B., and Ernst, C. H. *First Aid for Boys;* Boy Scouts of America. *Handbook for Boys.*

4. The walls of the left ventricle are much thicker than the right. The left ventricle does much more work than the right, as it pumps blood through the whole system. The right ventricle pumps blood only through the lungs which is a much shorter distance and so it has thinner walls.

5. Some likenesses and differences. Others will be found.

How like railroad system	*How different from railroad*
1) Carries supplies of food and other materials.	1) Materials are loaded into the blood and unloaded without stopping.
2) Has main and sub-branches.	2) Carrying parts in blood system almost never move backward.
3) Blood and trains follow definite paths.	3) Locomotives used instead of pumps.
4) Side tracks like capillaries for loading and unloading.	

6. (a) In the arteries. There is the greatest need for pressure here because in one case the blood must be carried to the head against gravity, and in the other it needs pressure to carry the blood back to the heart through the veins, and some of this is against gravity.
b) It is lowest in the veins. The lowest pressure in the system is in the veins closest to the heart. The flow of blood will always be toward the place of lowest pressure. This is where the blood ends its circuit before being pumped out on another round trip through the lungs or body.

PROBLEM 4: HOW DOES FOOD DISSOLVE AND GET INTO YOUR BLOOD? (P. 379)

The purpose of studying Problem 4 is to obtain a clear mental picture of the general structure and functioning of the alimentary canal. Most boys and girls have a vague notion of where the parts are but they do not visualize a tube leading through the body with glands pouring digestive chemicals on the food. Often they do not think of digestion as a dissolving process. The emphasis should always be on clear visualization and understanding rather than on memorization of book statements. The main ideas are:

1. While it is being digested, the food passes along a tube of varying diameter, which begins at the mouth and ends at the anus; parts of the food not dissolved and taken into the blood are stored in the lower part of the tube and passed out of the body at the toilet as solid wastes.

2. As the food is passed along by the contraction of muscles in the food tube, the digestive glands pour various fluids on the food.

3. Action of the teeth and muscles of the food tube breaks the food into small particles and mixes it with the digestive fluids.

4. The digestive fluids contain many special digestive chemicals, one or more for each particular kind of food substance. These chemicals change insoluble food substances into substances that will dissolve.

5. In the very long, small intestine the dissolved food soaks into capillaries and other tubes in tiny finger-like projections.

6. The digestive system can be helped by living a happy and relaxed life, by eating a properly varied diet, by keeping the teeth in good condition, and by using the teeth to chew food well.

SELF-TESTING EXERCISES (P. 381). 1. It will be well to have the diagrams for this exercise made all at one time after proper preparation. Each one should be checked to see whether the pupil visualizes the food tube as a tube with the salivary glands, liver, and pancreas pouring fluids into it.

2. The glands that pour digestive chemicals into food tube: (*a*) salivary glands; (*b*) glands in stomach lining (gastric glands); (*c*) glands in lining of small intestine; (*d*) pancreas; (*e*) liver.

EXPERIMENT 48. HOW DOES SALIVA HELP DISSOLVE FOOD? (P. 381). The apparatus and materials needed are:

Laundry starch or corn starch equal in volume to a pea
Beaker or small pan
Source of heat
Four test-tubes
Small glass or metal funnel
Cloth or cotton filter for funnel
Dilute iodine solution
One-half pint of water

a) The cooked starch mixture is cloudy, showing that the starch has not really dissolved. Iodine produces a blue or black color showing that starch is still present.

b) Filtering of the saliva is necessary to eliminate the cloudy mucus and leave a clear liquid. Iodine should show only a diluted brownish or yellowish color with the saliva.

c) Very soon after mixing the starch mixture with saliva its cloudiness should disappear. This is one indication that some change is occurring. Within a short time the iodine should give no blue or black color with the starch-saliva mixture. (A reddish color is often caused by a product of the starch digestion.) The saliva has changed the starch into some other substance that is soluble.

SELF-TESTING EXERCISES (P. 384). 1. The starch is acted upon, or digested, by the saliva and changed to sugar. The sugar dissolves in the water and is invisible. Thus it seems as if the starch had disappeared.

2. (*a*) By pushing the food from the one part of the tube to another.

b) By stirring the food and mixing it with the digestive juices.

3. The chemicals from the glands along the food tube help digest the food by changing each different kind of food into a substance that will dissolve and pass out of the intestine into the blood. For each kind of food substance that is to be changed there are one or more chemicals.

SELF-TESTING EXERCISES (P. 388). 1. Three reasons why the small intestine can absorb digested food rapidly: (a) It has a very thin lining; (b) It has a great many capillaries; (c) The lining has a large area.

2. Digested carbohydrates get into the blood by way of the capillaries in the villi lining the intestine. Digested fats go into small tubes called lacteals. From these they go into a long tube that empties into a vein near the shoulder. Thus the fats enter the blood in a roundabout way.

3. What happens to a piece of whole-wheat bread: (a) in the mouth:

1) It is broken up into small pieces by the teeth.

2) The saliva acts on it, and the starch in it is changed to sugar, if there is time.

3) Saliva moistens it so that it can be swallowed more easily.

b) In the stomach:

1) The muscles churn the bread about and mix it with gastric juice to form a creamy mixture.

2) Pepsin begins to change the proteins in the bread into soluble materials.

3) Partly digested food is pushed into upper intestine.

c) In the small intestine:

1) Digested further.

a) Bile from liver and pancreatic juice from pancreas enter and are mixed with food.

b) Bile and a chemical in the pancreatic juice make fats soluble and they dissolve.

c) Intestinal juice and pancreatic juice complete the dissolving of proteins and carbohydrates.

2) The dissolved foods are absorbed into the lining of the small intestine.

a) Digested forms of carbohydrates and proteins enter blood in capillaries.

b) Digested forms of fats enter the lacteals.

3) The remaining water and undigested material is pushed into the large intestine.

d) In the large intestine: The extra water is absorbed and the undigested parts of the bread are stored for awhile and then eliminated from the body.

4. Any food that does not dissolve is passed on to the large intestine. Here excess water is removed from it and it is pushed down toward the end of the large intestine, where it is stored until it is passed out of the body.

5. Three important ways of keeping the digestive system in order:
(*a*) Keep happy and interested in life. Avoid emotional disturbances, especially at meal times.
b) Keep your teeth in good condition and chew your food well.
c) Choose your food with care. Get the proper diet.

PROBLEMS TO SOLVE (P. 388). 1. After the cracker has been chewed for a long time, it should begin to taste slightly sweet as some of the starch is changed to sugar by the action of the saliva.

2. 160 feet (8 × 20).

3. Yes. When one thinks of eating or even about the flow of saliva into the mouth, then saliva flows.

4. Besides secreting bile the liver has several duties: (*a*) Before proteins are oxidized for energy, the liver removes the nitrogen from them and changes them into carbohydrates.
b) Nitrogen wastes in the blood are changed by the liver into the form which the kidneys can remove easily.
c) Sugar is stored in the liver in a special form known as glycogen.
d) Some iron is stored in certain liver cells.
e) One material in the blood that is essential for the clotting of blood is formed by the liver (i. e., fibrinogen).

5. The liver is supplied with blood from two sources. Some of it comes directly from the heart through an artery, but most of it has gone through the capillaries in the walls of the stomach and intestines before reaching the liver.

6. Quarreling at meal-time creates an emotional disturbance that affects the ability of the digestive glands to secrete the necessary digestive juices. It also affects the movements of the digestive organs. This may interfere with digestion.

PROBLEM 5: HOW DOES YOUR BLOOD GET OXYGEN AND GET RID OF CARBON DIOXIDE? (P. 389)

Again, most pupils have general information about the work of the lungs, but they are unable to visualize the paths of the materials that enter and leave the blood in the lungs. Clear visualization and appreciation of the fitness of the lungs to do their work should be the objectives of the teaching.

The main ideas to be gained are:

1. Air entering the breathing passages crosses the food tube in the throat and enters branching tubes that go into all parts of the lungs.
2. From the smallest of the air tubes the air enters and inflates millions of tiny air sacs that make up the bulk of the lungs.
3. Oxygen diffuses through the walls of the air sacs and enters the blood; at the same time carbon dioxide diffuses from the blood into the air sacs.
4. The used air is then breathed out.
5. We should protect our breathing system from dust, from infection, and from the results of abuse.

Experiment 49. What Is the Nature of the Lungs? (p. 389). The necessary apparatus and materials are:

Lungs and wind-pipe of a sheep (or a "sheep pluck") from a butcher

Large glass tube with rounded edges suitable for inflating lung

Sharp knife or scissors

If the "sheep pluck" (lungs, heart, and liver) is obtained, the lung arteries may be traced into the lungs from the heart.

Self-Testing Exercises (p. 395). 1. The molecule, bouncing first this way and then that way, gradually works its way through the moist lining of the air sac and then through the wall of the capillary into the rushing stream of blood. (In the blood it moves into a red corpuscle and unites with a molecule of hemoglobin.)

2. This story should be the almost exact reverse of Exercise 1.

3. The air breathed out has less oxygen and more carbon dioxide, as well as more moisture.

4. (a) Keep in good physical condition by getting enough rest, the right kind of food, fresh air, and a reasonable amount of exercise. *b*) Avoid contact with germs of respiratory diseases, if possible. *c*) Avoid breathing in dust and similar materials as much as possible.

Problems to Solve (p. 395). 1. In the rushing blood the oxygen molecule is carried to the heart, pumped out into the artery, enters a capillary (in a leg muscle, for example), diffuses into a muscle cell, unites with some carbon from a food molecule becoming carbon dioxide, diffuses into the blood in a capillary, is swept into a vein, into the heart, and then through an artery into a lung capillary again.

2. (a) They have a very large surface for taking in oxygen. *b*) Walls of air sacs thin and easily permit oxygen to get through. *c*) The lining of the air sacs is moist so that the gases dissolve. *d*) There are many blood vessels to carry the blood to and from each air sac.

7. During one hour of the day. During the day the body is active and needs more energy. Therefore, more oxygen is required to obtain energy from the food materials in the cells.

8. Study of a pulmotor and its use.

9. Tonsils may become infected and harbor germs that make toxins which spread throughout the body making us ill. Adenoids often become enlarged and interfere with the free passage of air to the lungs.

PROBLEM 6: HOW DOES YOUR BODY GET RID OF ITS NITROGEN WASTES? (P. 397)

The discussion of Problem 6 is designed to form in the minds of pupils a useful image of how the kidney system is constructed and does its work. The main ideas to be brought out are:

1. Nitrogen wastes of the body are soluble solids and must be removed in solution.
2. Myriads of tubules that make up the kidneys separate the water and nitrogen compounds from blood and form urine.
3. The urine is stored in a muscular sac, the bladder, from which it is occasionally discharged.
4. In addition to removing wastes, the kidneys help keep the blood composition correct.

SELF-TESTING EXERCISES (P. 399). 1. They remove nitrogen wastes from the blood and help regulate the different materials in the blood.

2. The kidney is composed of about a million very small tubes, called tubules. These are connected by a network of capillaries. At one end of a tubule water filters out of the blood. In some of the

cells in the center of the tubule, water is taken from the urine and returned to the blood. From these tubules the waste material passes down with the remaining water through a ureter to the urinary bladder.

3. The kidneys are connected to the bladder by means of tubes called the ureters. Connection with the bladder is necessary in order to store the urine until it can be discharged from the body.

LOOKING BACK AT UNIT 8 (P. 399). Refer to the unit graph, page 189.

1. Pupils' summaries should contain many of the main ideas listed in this *Guidebook* at the beginning of each problem in this unit. The teacher may use these lists as a guide in checking pupils' summaries. One summary might contain these ideas:

The body consists of myriads of living cells that do all its work. Bones and muscles hold the body up and move it about. Cells that form the digestive system take in food, dissolve it, and put it into the blood. The lungs take in oxygen and let it diffuse into the blood. Blood with dissolved food and oxygen is pumped by the heart through thin-walled capillaries that lie near every cell in the body. From the blood food and oxygen diffuse into cells all over the body.

In the cells food is oxidized to release energy for use of the cells and to keep the body warm. Used materials, principally carbon dioxide and nitrogen compounds, diffuse back into the blood. In the lungs carbon dioxide diffuses into the air sacs and is breathed out. Kidneys remove nitrogen compounds from the blood, and they leave the body in urine. Thus each living cell receives what it needs to do its work and has its wastes removed.

2. A *vein* is one of the tubes that carry blood to the heart from all parts of the body.

Urea is a chemical compound that contains nitrogen wastes and is found in urine.

A *villus* is one of the thousands of finger-like projections in the small intestine that help absorb food.

Tendons are strong, tough bands or cords that connect muscles to bones.

Vertebrae are the bones that make up the backbone.

Glands in the body make and give out substances needed by the body.

Cartilage is the firm, elastic, flexible substance forming parts of a skeleton.

Capillaries are tiny blood vessels that connect arteries with veins.

A *ligament* is a band of strong tissue that connects bones or holds parts of the body in place.

Oxidation is a chemical process in which oxygen combines with another substance.

The *alimentary canal* is the long food tube in the body running from the mouth to the anus.

Bronchial tubes are the branches of windpipe going to lungs.

The *diaphragm* is a wall of muscles and tendons separating the chest cavity from the abdominal cavity.

Gastric juice is the liquid produced by glands in the stomach wall to digest certain foods.

A *system* of organs is made of different organs, each one doing some particular kind of work in the body.

Arteries carry blood from the heart to all parts of the body.

Diffusion is the way in which a material moves from one place to another by the movement of the separate molecules.

Two *ureters*, one from each kidney, are tubes through which urine goes from the kidneys to the bladder.

Corpuscles, red or white, are blood cells that make up the solid part of the blood.

Cilia are tiny living, moving hairs, such as those on the linings of the breathing passages.

ADDITIONAL EXERCISES (P. 400). 1. Upon exercising: (*a*) The heart beats more rapidly.

b) The lungs take in more oxygen and give out more carbon dioxide. Rate and depth of breathing become greater.

c) More food material is oxidized; more heat produced in the body.

d) The circulation of the blood is speeded up. More blood goes to the surface of the body.

e) Sweat glands become more active and give off perspiration.

f) Kidneys are stimulated to greater activity.

2. Uses of water in the body: (*a*) Helps dissolve our food.

b) Acts as a carrying substance for dissolved materials that move through the body.

c) Makes up an important part of the blood.

d) Forms a large part of protoplasm.

e) Carries off some of the waste materials.
f) Cools the body by evaporating from the skin.

4. The water becomes cloudy or milky. As the fish breathes it gives off carbon dioxide (CO_2) into the water. The carbon dioxide unites with the limewater [$Ca(OH)_2$] to form a cloudy mixture.

7. Comparison of heart and water pump (that uses a piston).

How Alike	*How Different*
a) Both are used to move liquid.	a) Pumps use air-pressure.
b) Liquid flows out in pulses.	b) Whole heart contracts to force liquid out; pump uses piston.
c) Has both intake tube and discharge tube.	
d) Has valves to prevent backward flow of liquid.	c) Heart pumps liquid through a closed circuit.

PAMPHLETS AND BULLETINS FOR UNIT 8

Public Health Reprint. No. 1203. *Artificial Respiration.* 5c
Public Health Reports. Supplement 149. *Good Teeth.* 5c

VISUAL MATERIAL

MOTION PICTURES

Encyclopaedia Britannica Films: "The Blood"; "Body Framework"; "Breathing"; "Circulation"; "Circulatory Control"; "Digestion"; "Muscles"; "Posture"; "The Skin"; "Care of the Teeth"

International Dental Health Foundation for Children, Inc., 130 East End Avenue, New York. "Say It With Pearls."

FILMSTRIPS

Society for Visual Education: "Bones and Muscles"; "Blood and Circulation"; "Respiration—Skin—Kidney"; "Foods and Digestion"; "Nervous System—Eye, Ear, Tongue."

CHARTS

Children's Bureau. *Position of Skeleton in Good and Poor Posture.* 34 × 24 in. 5c

Johnson and Johnson, Tek Toothbrush Division, New Brunswick, N. J. *Arrangement and Care of Teeth.* Chart, 24 × 36 in. (free)

Metropolitan Life Insurance Co., 1 Madison Ave., New York. *Safety Charts* (free)

United States Office of Education. Educational Chart G 91 (3). *Teeth and Their Structure.* 15 × 12 in. 5c

UNIT 9

How Can You Help Your Body Fight Disease?

FUNCTION AND SCOPE OF UNIT 9. This is the second unit in the book that is devoted entirely to health. Unit 8 dealt with the human body as a working machine and emphasized the fact that the best safeguard of our health is the keeping of the body in good physical condition. However, there are some germs that can attack the body successfully even though it is in the best possible condition. This unit therefore emphasizes the nature of disease germs, the methods by which germs are spread, the production of toxins and the effect of these toxins on the body, the body's protection against germs, the best ways of helping the body protect itself, and the methods of preventing or decreasing the spread of germs. Refer to the graph, page 215.

INTRODUCTORY EXERCISES (P. 402). *2. Bacteria are very small one-celled plants that belong in the same group of plants as the fungi.

4. Some suggestions are: (a) Keep oneself in good condition all the time.

b) Get plenty of sleep.
c) Eat the right kinds of food.
d) Get plenty of fresh air and sunshine.
e) Keep one's body and clothing clean.
f) Screen buildings against insects.
g) Be vaccinated against infectious diseases.
h) Be sure milk is pasteurized.
i) Know what the source of water supply is.
j) Take care of cuts and scratches by using an antiseptic and clean bandages.
k) See the doctor regularly for examination.
l) Keep food in a clean, cool place.
m) Keep away from persons who have infectious diseases.
n) If one does get sick, see the doctor quickly.

5. (*a*) Two definitions are possible. (*1*) Germs are microscopic plants or animals that cause disease. (*2*) Germs are any of the very small living things.

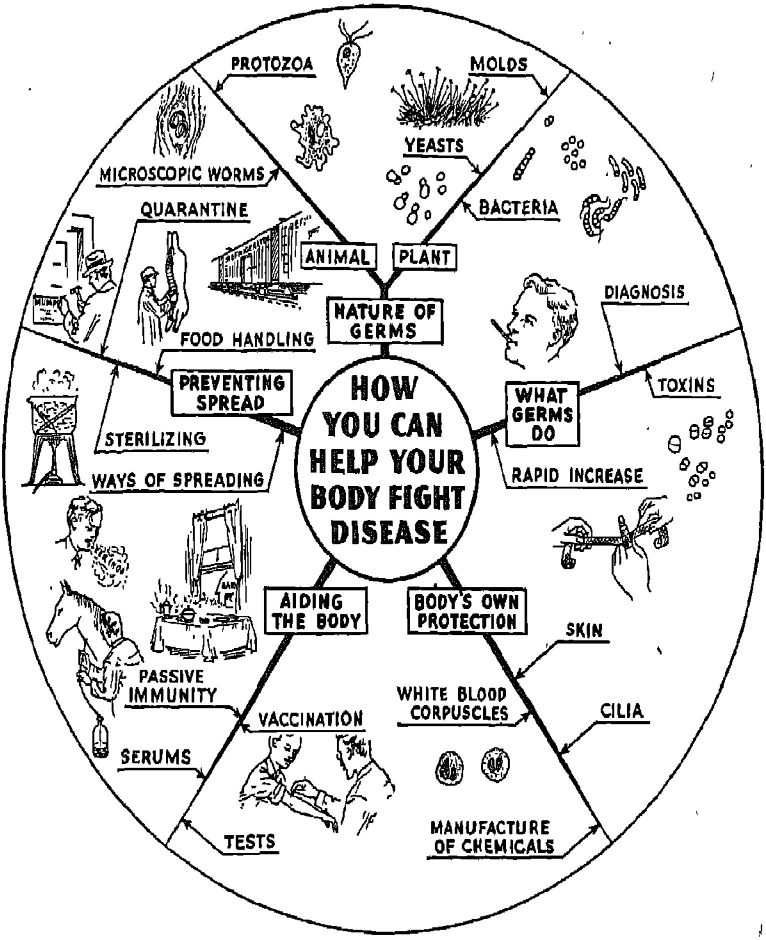

FIG. 16. GRAPH OF THE SUBJECT MATTER OF UNIT 9

b) According to definition 1, yes. According to definition 2, no.

c) A "germ" disease is one that is caused by one of the very small organisms, called germs, as distinguished from a disease that is organic, or not caused by an infecting agent.

6. Germs harm: (a) by using for food the materials that the body should be using.

b) By destroying cells and tissue.

c) By giving off poisons that spread throughout the body.

8. Insect-carried diseases that may be named are:

a) *Typhoid fever.* Externally on filth on flies' bodies.

b) *Malaria.* Germ lives inside of mosquitoes' bodies.

c) *Yellow fever.* Germ lives inside of mosquitoes' bodies.

d) *Bubonic plague.* Germ carried by rat fleas.

9. Both statements mean that it is much better to take measures to preserve health than it is to have to cure people when they become ill.

LOOKING AHEAD TO UNIT 9 (P. 403). This section emphasizes (1) the fact that one's health is a very valuable asset and (2) that there are available to us today scientific ways of combating disease instead of the unscientific ways of the "medicine-men" and patent medicines. Undoubtedly, some pupils in the class will come from homes in which these unscientific ways are practiced. The teacher can supplement the ideas in the text by giving more examples of the methods of treating diseases in early days and showing how many of these practices still exist.

PROBLEM 1: WHAT ARE DISEASE GERMS? (P. 406)

This problem is a survey of the different types of parasites that cause disease, with examples of the diseases caused by each type. The main ideas are as follows:

1. Scientific workers have proved that many diseases are caused by tiny living organisms called disease germs.

2. Microscopic plants, both harmful and harmless, exist almost everywhere in the air, soil, and water, and on and in the bodies of men and other animals; some of these are disease germs.

3. Some diseases are caused by one-celled animals and by tiny parasitic worms.

4. Some diseases are spread like germ diseases, but scientists have been unable to see the germs that cause them.

Self-Testing Exercises (p. 407). 1. A very small plant or animal that causes disease in other plants or animals.

2. Organic disease is one in which some organ of the body does not work properly. Heart trouble is an example of this.

A germ disease is one caused by a germ that infects the body. Diphtheria is a germ disease.

Experiment 50. Where Are Bacteria Found? (p. 410). The apparatus and materials needed are:

Six Petri dishes, 100 mm. dia.
Pan, large, for sterilizing
Cover for pan
Five ounces unflavored granulated gelatine
One quart water
Pinch salt
One-half ounce beef extract (or sugar)
Toothpicks
Milk
Bunsen burner
Wire gauze
Ringstand and ring

The directions for this experiment are presented in such detail that no difficulty will be experienced.

This experiment provides a good opportunity for showing concretely how a *controlled* experiment works. It is controlled because two parts of an experiment are performed in the same way except for one thing, and any difference in the results is caused in some way by the one thing that is different. There are really several controlled experiments being done at once in Experiment 50, but only one "control" dish is used.

Self-Testing Exercises (p. 412). 1. No. Some are helpful in getting rid of dead plant and animal bodies, in taking nitrogen from air and making it into useful compounds, and in aiding various industrial processes.

2. (*a*) Chains of small spherical bacteria. (*b*) Spiral.

3. Diphtheria, typhoid fever, tuberculosis, leprosy, whooping cough, scarlet fever, pneumonia.

4. Correct statement: All bacterial diseases are germ diseases. The term germ includes other microörganisms than bacteria There-

fore, some germ diseases are not bacterial diseases but are caused by germs belonging to other groups of organisms.

SELF-TESTING EXERCISE (P. 414). The diseases are divided into lists as follows:

Plant Germs	*Animal Germs*	*Uncertain*	*Many-Celled Animals*
scarlet fever	malaria	common cold	hookworm
pneumonia	African sleeping sickness	influenza	trichinosis
typhoid fever		mumps	
tuberculosis		measles	

PROBLEM 2: HOW DO GERMS MAKE US SICK? (P. 415)

Knowledge of the nature of germs and their production of poisons, or toxins, is fundamental to an understanding of this unit. The discussion of these ideas, therefore, furnishes the material for the second problem of the unit. Following are the main ideas emphasized in this problem:

1. The favorable growing conditions in human bodies enable germs to multiply very rapidly unless they are hindered by the body.

2. Germs, growing in their favorite places in our bodies, destroy cells and give out poisons that cause the symptoms of each different disease.

3. Doctors tell what kind of disease a person has by making a diagnosis, that is, by discovering the signs, or symptoms, present.

SELF-TESTING EXERCISES (P. 418). 1. (*a*) They need food, moisture, and warmth. (*b*) They need darkness instead of sunlight.

2. Sixteen. The supply of food is used up, and they are gradually poisoned by their own waste products.

3. A toxin is a poison made by germs as they grow. It may spread throughout the body and poison or seriously affect the workings of various organs.

4. By means of symptoms, or signs. These include feelings of the patient, such as fever, chills, headache, etc., and various external evidences, such as rash, pus, etc.

Problems to Solve (p. 418). 2. The symptoms of a few diseases are: (a) *Malaria*. Rising temperature, then chilling with shivering, etc., followed by feeling hot with headache and thirst. Then sweating occurs. These stages together last 6-12 hours; these are repeated in 1, 2, or 3 days.
b) *Pneumonia*. Severe chilling, pain in side, fever, rapid breathing, dry, painful cough, flushed face, coated tongue, constipation.
c) *Typhoid fever*. Rising temperature, nausea, lack of appetite, headache, pains in back and limbs, nose bleed. Fever reaches 103° to 105° after a week. Pink spots may appear on abdomen.
d) *Influenza*. General aches in body, including headache, fever, chills, followed by extreme weakness. High temperature at beginning.

PROBLEM 3: HOW DO OUR BODIES FIGHT DISEASE? (p. 418)

From the study of the preceding problems pupils become so impressed with the universal presence of germs that they are often unnecessarily fearful of infectious disease, believing as they do that any and all of these germs can enter the body and cause disease. Problem 3, therefore, has as its purpose to show that the body is quite well protected against germs externally and internally. Emphasis should be given to the function of the white corpuscles. The main ideas of the problem are:

1. The body has effective barriers that keep most germs from reaching its inner parts.
2. Inside the body are countless traveling cells, called white corpuscles, that take in and destroy germs that get through the outer barriers; these white corpuscles in the blood increase in number when there are germs in the body.
3. When attacked by some kinds of germs, our bodies are able to manufacture chemicals that help overcome the germs and their poisons.
4. After attacks of certain diseases the special chemicals remain in the body and make us immune to that disease.
5. The general condition of one's body makes a great difference in its ability to fight such diseases as pneumonia, tuberculosis, and colds.

SELF-TESTING EXERCISES (P. 419). 1. (*a*) By the protective layer of skin that keeps germs out; (*b*) by cilia that sweep germs out of air passages; (*c*) by sticky liquids that catch and stick the germs together. Then germs are expelled by sneezing and coughing.

2. (*a*) Squeeze the wound, so that it will bleed. This helps wash out any germs that may be present.
b) Paint the wound with iodine, or other good antiseptic, and bandage with a piece of sterile gauze. Iodine will kill germs, and gauze will prevent a new infection.
c) Go to the doctor. Tetanus may develop from such a wound.

SELF-TESTING EXERCISES (P. 421). 1. They travel to places where germs are, attack the germs, and either kill them or change them into harmless substances.

2. That there is an infection somewhere in the body, because the body is making extra white corpuscles to fight the infection.

SELF-TESTING EXERCISES (P. 423). 1. The chemicals produced in the blood to fight germs and toxin while the person was having the disease remain in the body for the rest of his life.

2. (*a*) Scarlet fever, diphtheria, mumps, measles.
b) Colds, influenza, tuberculosis, pneumonia.

3. Probably because the body was in such good condition that it was able to make enough germ-fighting chemicals to keep the cold germs from making you ill.

PROBLEM 4: HOW CAN WE HELP OUR BODIES FIGHT DISEASE? (P. 423)

Whatever we may do in trying to keep in good physical condition or in protecting ourselves from disease germs, there come times when these germs do get into our bodies and cause sickness. In such cases an intelligent person calls upon an expert for advice and care. Pupils should be led through Problem 4 to take this intelligent attitude, and particularly to avoid, in case of illness, quack doctors and patent medicines. Following are the main ideas of the problem:

1. Various kinds of vaccinations can cause the body to make germ-fighting chemicals before it becomes sick and thus keep it from taking certain diseases.

2. Germ-fighting chemicals made in the bodies of various animals can be injected into our bodies to help them overcome some kinds of germs.

3. Special tests are used by doctors to find whether a person is immune to certain germs or whether he already has the germs in his body.

Self-Testing Exercises (p. 427). 1. When the girls had cowpox, their blood manufactured antibodies that were able to fight the smallpox germs. These antibodies stayed in their blood, and when the girls were exposed to smallpox, they did not take it.

2. It means that it will not take a certain disease because the blood has antibodies that fight the germs of that disease.

3. The Dick Test shows whether or not a person is likely to take scarlet fever. The Schick Test shows whether or not a person is likely to take diphtheria.

PROBLEM 5: HOW CAN WE HELP PREVENT THE SPREAD OF DISEASE GERMS? (p. 427)

This problem takes up first the methods by which germs are spread or transmitted and then discusses the ways of preventing the spread of germs by each of the methods and the idea that preventive medicine is the best method of keeping well.

1. To spread infectious diseases, germs must pass from sick persons or animals, or from "carriers," to other persons.

2. The germs get from person to person in almost every possible way—by direct contact, on articles that are handled, in food and drink, by insects, etc.

3. Appropriate methods of avoiding contact, killing germs, and controlling insects prevent the spread of germs and their entrance into our bodies.

4. It is much better to avoid having a disease than to try to cure it after a person has it.

Self-Testing Exercises (p. 432). 1. Yes. Sometimes a person can carry the germs of a disease in his body and be a source of infection for others although he himself is not sick from the disease. This is often true in the case of typhoid fever. A person sick with the disease is, of course, a carrier of the disease.

2. (a) *By body discharges of, and objects handled by sick people.* Keep sick people away from others. Sterilize objects and fumigate rooms.
b) *By some one who is sick and does not know it.* Do not handle objects that might have germs on them.
c) *In foods.* Handle carefully, pasteurize, refrigerate, test cows.
d) *By insects.* Destroy rubbish, screen houses, and otherwise keep insects away.

3. (a) Quarantine the sick person, or keep other people away by other means.
b) Do not allow people who have disease germs to handle food, etc., that will be used by well persons.
c) Carefully sterilize all dishes, implements, etc., used by the sick person before they are used by someone else.
d) Fumigate the room where a sick person has stayed.
e) Take care that flies and other insects cannot carry germs from sick to well persons by way of food, etc.
f) A person who has the care of a sick person must be sure to disinfect his hands and take other precautions to avoid carrying the disease to well people.

4. Paint the cut or scratch with iodine, or some other good antiseptic, and put a clean bandage over it.

PROBLEMS TO SOLVE (P. 432). 2. Disease epidemics could be started by:
a) Infected water supply.
b) Infected dairy cattle.
c) A sick person handling milk.
d) Unpasteurized milk.
e) Failure to vaccinate.
f) Improper sewage disposal system.
g) Carriers working in restaurants or as other types of food handlers.

SELF-TESTING EXERCISES (P. 435). 1. Answers will vary. Pupils will probably list such things as sleep, exercise, proper eating, brushing teeth, keeping clean, going to the dentist, etc.

2. Answers will vary. Some practices that pupils may list are:
(a) Have a doctor check the body at least once a year to see if it is in good condition.
b) Keep away from persons who have bad colds.

c) Take care of small wounds, such as cuts and scratches, so that they will not become infected.

d) Be vaccinated against infectious diseases.

e) Turn face away when anyone is coughing or sneezing.

3. Answers will vary. They may include safe water supply, clean milk and food supply, quarantine laws, school nurses, clean streets and homes, insect control, etc.

LOOKING BACK AT UNIT 9 (P. 435). 1. Pupils' answers to this should include the main ideas listed on pages 216, 218, 219, 220, and 221 of the *Guidebook*.

2. *Cilia* are microscopic living hairs such as those that cover the linings of the breathing passages.

A *toxin* is a poison produced in the bodies of animals by germs.

A *vaccine* is a substance that is put into the body to produce a mild form of a disease. This causes the cells to manufacture chemicals which stay in the body and protect one against the real disease.

When a certain infectious disease spreads so rapidly that many people have it at one time, we have an *epidemic*.

Coccus is a ball-shaped, or spherical, bacterium.

A *carrier* is a person who carries the germs of an infectious disease in his body and may give it to another person, although he himself may not be sick with the disease.

An antitoxin is a substance formed in the body that acts against the poison produced by germs. It is also a substance that has been manufactured by an animal having a certain disease and that can be put into the blood of another animal to help resist the poisons given off by germs.

Vaccination is the process whereby a vaccine is put into the body to cause it to make chemicals to fight the vaccine and thus make the body immune.

A disease is recognized by the peculiar *symptoms*, or signs, that it gives the doctor.

Bacillus is a cylinder-shaped bacterium.

Active immunity is produced in the body when the body works against germs or their toxins and produces its own antibodies.

Passive immunity is produced in the body when antitoxins that are made outside the body are put into it. The body is passive, that is, does nothing about making the antitoxins.

The *incubation period* is the number of days between the time the germs enter the body and the appearance of the symptoms of the disease.

An *infectious disease* is caused by growth of germs in the body and may be easily spread from one person to another.

An *organic disease* is caused when some organ of the body doesn't do its work properly.

An *antiseptic* is a chemical that prevents the growth of germs.

Fumigation is the process of exposing a room in which a person has been sick with a contagious disease to vapor in order to kill the germs.

Pasteurization is the process of killing germs in milk by heating it to 144° F. for about 30 minutes.

Sterilization is the process of killing germs on objects by heating the objects in boiling water or live steam or by dipping them in chemicals.

Spirillum is a spiral-shaped bacterium.

ADDITIONAL EXERCISES (P. 436). 1. Certified milk is raw milk produced with very special care and having a bacterial count not to exceed 10,000 per cc. Pasteurized milk is milk that has been heated at 144° F. for about 30 minutes, to kill disease germs. It may have a comparatively high bacterial count that varies with the grade.

Certified milk is much more expensive than pasteurized milk. The low bacterial count is obtained by extreme care in handling. This extreme care involves a considerable expense to the dairyman, and thus the milk is higher in price.

2. Although the main purpose of the pasteurization of milk is to kill any possible disease germs in the milk, it may incidentally kill some of the organisms that cause the milk to sour. For this reason pasteurized milk may keep longer without souring than ordinary raw milk, but it does sour eventually. It does not keep longer than certified raw milk, however.

3. The mercuric chloride is a germicide and kills the milk-souring bacteria in the milk. Thus, the milk without the germicide sours while that containing the mercuric chloride does not. (Under no condition must the milk treated with mercuric chloride be tasted, but it may be well for the teacher to know that raw eggs are an antidote for mercuric-chloride poisoning.)

BULLETINS AND PAMPHLETS FOR UNIT 9

Metropolitan Life Insurance Co., 1 Madison Ave., New York, N. Y.
Pamphlets on Health and Disease Prevention (free)

National Education Association of the United States, 1201 Sixteenth St., N.W., Washington, D. C.
Pamphlets on child health education (Write for price list.)

United States Department of Agriculture
Agricultural Leaflet No. 177. *Pasteurization of Milk.* 5c
No. 182. *House Fly Control.* 5c
Farmers' Bulletin. No. 602. *Production of Clean Milk.* 5c

United States Public Health Service
Bulletins on Cause and Prevention of the Common Communicable Diseases
Public Health Reports. Supp. 135. *Common Colds.* 5c
Supp. 18. *Malaria, Lessons on Its Cause and Prevention for Use in Schools.* 10c
Supp. 29. *Transmission of Disease by Flies.* 10c

VISUAL MATERIAL

Motion Pictures

Encyclopaedia Britannica Films: "Bacteria"; "Diphtheria"; "First Aid—Care of Minor Wounds"; "The House Fly"; "Body Defenses Against Disease"

Filmstrips

Society for Visual Education: "Microorganisms and Disease"; "Relation of Insects to Disease"; "How Plants and Animals Cause Disease"; "How Disease Is Spread"; "How the Mosquito Spreads Disease"; "Swat the Fly"; "The Fly as a Disease Carrier"

Charts

Fisher Scientific Co., Pittsburgh, Pa.
Laboratory Emergency Chart. About 16 × 25 in. (free)

National Safety Council, 168 North Michigan Ave., Chicago, Ill.
Laboratory Posters on First Aid. 8½ × 11 in. (free)

United States Public Health Service, Washington, D. C.
"Exterminate that Fly!" 13.9 × 11 in. 5c. $1.00 per 100 copies.

UNIT 10

How Does Life Continue Upon the Earth?

FUNCTION AND SCOPE OF UNIT 10. Practically all educators are agreed that pupils should understand and accept the process of reproduction as one of the important life functions of all living things. Since reproduction is a normal part of the life cycle, no undue stress should be placed upon the teaching of it. The material should be presented in a sincere straightforward manner, since attempts to "sidestep" or "hedge" will quickly be detected by the pupils.

Experience has shown that the old "pollination story" alone is unsatisfying to pupils, oftentimes leaving them to seek more satisfactory information from undesirable sources. This unit attempts to avoid such difficulty by presenting along with the story of reproduction of plants, the story of how higher animals reproduce. Much use is made of the similarity of the way in which animals and plants reproduce in order to establish clearly the universality of this process among living things.

Reproduction and growth are so intimately associated that it is impossible to consider one without the other. Because of this relationship and to give a more complete picture of the life cycle of living things, much of the unit is devoted to the growth of young plants and animals into mature individuals.

It is hoped that the teacher will carefully study the unit as a whole and realize its possibilities for his particular group. The most desirable outcomes of the study of this material on growth and reproduction are: (1) an intelligent understanding and appreciation of the remarkable way in which living things perpetuate their species and (2) a wholesome outlook upon this profound and vital phase of life.

INTRODUCTORY EXERCISES (P. 438). *1. The smallest unit of living material of which most living things are made up.

*2. Protoplasm (including cytoplasm and nucleus) and cell wall or cell membrane, as the case may be.

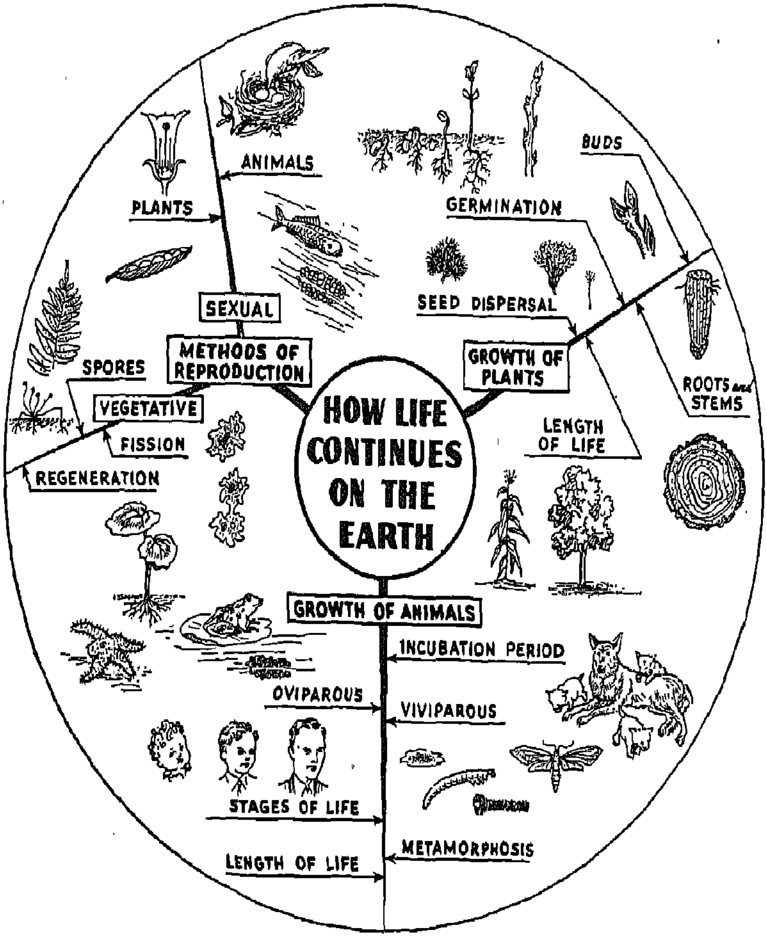

FIG. 17. GRAPH OF THE SUBJECT MATTER OF UNIT 10

3. Seeds, cuttings, bulbs, tubers, runners, layering, grafting may all be named.

4. (a) Birds, some snakes; turtles, fish; frogs.

b) Yes but they are developed in the body of the mother rabbit and born alive.

5. Parts of bean seed and hen's egg: (a) *Parts alike:* Protective covering (seed coat and shell); Embryo (young plant and chicken); Stored food for embryo (cotyledons and most of yolk and white).

b) *Parts different:* All parts are different in structure.

7. List of changes:

a) Gain in weight
b) Gain in height
c) Teeth—2 sets
d) Mental changes
e) Possible hair changes
f) Change in shape of face and body

8. Changes in plant:

a) Roots and first leaves develop from embryo in seed.
b) Plant grows taller.
c) Other leaves that develop are perhaps different from first leaves.
d) More branches appear.
e) Stem grows larger around.
f) Flowers appear.
g) Flowers fall off and fruits with seeds appear.

*9. Green plants make food by the process of photosynthesis. That is, they make food from water and minerals in the soil and carbon dioxide in the air, with the help of the green coloring material in the leaf and the energy of the sun.

*10. Root-hairs take in water from the soil. They are so small that they can take the moisture from around the tiny soil particles. They are so numerous that they give the plant a large amount of surface for water absorption.

*11. In series of tubes contained in the fibrovascular bundles. One set carries water and minerals from the soil up through the plant, and the other carries food from the leaves, where it is manufactured, down through the plant.

12. No. Most plants in the cold climates are dormant in the winter. The leaves have fallen and food manufacture is not being carried on. Therefore, the supply of energy-supplying material is less, and growth is less active if it occurs at all. Different growing conditions during the other seasons make the growth rate vary also.

LOOKING AHEAD TO UNIT 10 (P. 439). Since this unit is likely to be taught in the early spring, the discussion of birds building their nests, laying eggs, and hatching young make a timely introduction. Letting the children supplement this discussion with instances from their own observations provides a natural introduction and approach to the material which is to follow.

These introductory pages attempt to accomplish the following: (*1*) to show what is meant by *spontaneous generation*, (*2*) to show how the use of the scientific method has disproved the idea of spontaneous generation, and (*3*) to provide an overview of the material of the unit (reproduction, growth, and the life cycle.)

PROBLEM 1: WHAT ARE SOME OF THE WAYS IN WHICH LIVING THINGS REPRODUCE? (P. 442)

Fission is the simplest way in which animals and plants reproduce. Reproduction by means of this process is clearly presented for both plants and animals. Other more complicated asexual methods of reproduction are dealt with as the problem proceeds from simple to more complex processes—reproduction of plants by means of spores and from parts of plants. The more complicated processes of reproduction by means of sexual methods (higher plants and animals) complete the story of how living things perpetuate their species.

During the study of the increasingly complex processes of reproduction the similarity of the product of these processes (resulting in new, free-living organisms) should be stressed.

A good supplementary laboratory experience for the pupils to have during the study of this problem is to bring to the classroom a pair of animals such as white mice, white rats, rabbits, or guinea pigs. In most cases the male must be kept in a separate cage to avoid his injuring the young animals. Have the animals bred previously so that the young will be born soon after the adults are brought into the laboratory. Have the pupils learn the proper care of the young, weigh them, and keep records of their growth.

The main ideas to be stressed during the study of this problem are:

1. The simplest method of plant and animal reproduction is division into two separate organisms, each of which is like its parent.
2. Some kinds of plants produce many spores, each of which can develop into a new plant.
3. Some plants and animals can regenerate missing parts, or develop new individuals from parts of these individuals.
4. Higher plants and animals reproduce by the union of egg and sperm cells.
5. In higher animals and plants there is an increased specialization of reproductive parts.

EXPERIMENT 51. HOW DO THE SIMPLEST PLANTS REPRODUCE? (P. 443). The apparatus and materials needed are:

Pieces of tree bark with Pleurococcus growing on it
Microscope
Glass slides (and cover slips if high power is to be used)

About all that can be expected of the pupils from this exercise is the observation of single Pleurococcus plants and groups of these plants. Sketches of these should be made by the pupils and kept in their notebooks. The protoplasm will be clearly visible, while the nucleus may or may not be visible depending upon the condition of the plants and the use of the microscope. Pleurococcus usually grows on the north side of tree trunks, since this is the shaded side.

Having a prepared, stained slide for observation (if living material cannot be obtained) is recommended. However, in all cases wherever it is at all possible, living material should be used first, and the prepared material should be used as supplementary after living specimens have been studied. Observation of living specimens of amoeba and prepared slides of fission of amoeba are excellent supplementary experiences.

SELF-TESTING EXERCISES (P. 444). 1. The living material of which all things are made.

2. The nucleus is a denser part of the protoplasm that controls the growth and other activities of the cell.

4. 1024.

EXPERIMENT 52. HOW DOES THE BREAD MOLD REPRODUCE? (P. 444). The apparatus and materials needed are:

Bread
Blotter
Two glass dishes with tight covers

The most common kind of bread mold, *Rhizopus nigricans*, is the kind that is likely to grow upon the bread in the dish. Have the pupils observe the mycelium from time to time and make sketches of different stages of progress through the ripening and rupturing of the spore cases. Stress the fact that the ripened, dark knobs are spore cases containing many spores. Examine ripened spores under the microscope. Part *b* of the experiment is planned to show the completion of the life cycle from spores to mature plants with reproductive parts. Part c shows that the spores cannot develop on dry bread.

SELF-TESTING EXERCISES (P. 447). 1. Spores are small cells, usually with thick coats, that can produce new plants.

2. The mycelium appears as a mass of fine white threads. At the ends of some of the branches of the mycelium tiny white balls appear. As they grow older, the balls turn black. These balls are the spore cases and contain many tiny spores. The hyphae, which make up the mycelium, grow through the material the fungus is growing on and get food from it. The spore cases contain the spores which reproduce the fungus.

PROBLEMS TO SOLVE (P. 447). 1. List of spore-bearing plants not mentioned in text: certain of the green algae; liverworts; lichens; other fungi than the bread mold, such as mushrooms, etc.

3. (a) In reproduction by simple fission, only two new bodies are formed. In reproduction by spores many new individuals can be formed from one individual.
b) In both methods of reproduction there is separation of protoplasm in the parent organism and each bit of separated protoplasm can grow into a new individual.

4. (a) Protect the bread from exposure to dust which contains mold spores.
b) Keep bread in a box that is well ventilated so that the bread will not get warm and damp. Bread mold spores need moisture and warmth to make them germinate.

EXPERIMENT 53. HOW CAN NEW PLANTS BE REPRODUCED FROM PARTS OF PLANTS? (P. 447). The materials and apparatus needed are:

Pussy-willow branches
Long slender sweet potato
Geranium cutting
Begonia (and Bryophyllum leaves if possible)
Irish potato
Bulbs (paper white narcissus are good)
Glass containers
Sand
Flower pots
Moist soil

These experiments should be started by pupil groups two or three weeks before their anticipated use in this problem. In this way, the plants will have developed their missing parts to the stage where they can easily be observed. Have the pupils examine, discuss, and make sketches of the parts of the plants. Wash soil or sand from the roots of specimens so that observations may be more easily made.

SELF-TESTING EXERCISES (P. 451). 1. A piece of the parent plant such as a leaf or stem is separated from the plant and develops the missing parts to become an entire plant.

2. (a) A new organism or organisms are produced from a part of the parent plant.
b) In reproduction by spores a specialized body, the spore, is made by the plant for use in reproduction. In regeneration one of the usual parts of the plant, such as stem, leaf, or root, is used to start a whole new individual.

3. Potatoes, geraniums, some grasses, strawberries.

4. (a) Sweet potato. (b) Bryophyllum. (c) Irish potato, willow.

5. A rhizome is an underground stem. A stolon is a long stem that runs along the surface of the ground.

PROBLEMS TO SOLVE (P. 452). 1. (a) *Useful to man:* (*1*) He can reproduce the plants that have the characteristics he likes and be sure that he will obtain the plant he wants.

2) Some plants are hard to grow from seed, and man can often reproduce these by regeneration.

3) Some plants do not produce seeds under all conditions, and these plants can be reproduced by cuttings when desired.

b) *Harmful to man:* (*1*) Sometimes reproduction by regeneration makes it very easy for undesirable plants to spread and makes it difficult to eradicate them.

2) Regeneration of starfish may make control in oyster beds difficult.

2. Because the buds are at the nodes and the cutting must have buds to grow into new leafy shoots after roots have started to grow.

EXPERIMENT 54. HOW DO FLOWERS PRODUCE SEEDS? (P. 452). The materials and apparatus needed are:

Large perfect flowers such as lilies or primroses
Hand lenses for examining small parts are desirable.

This experiment is best handled as an individual laboratory exercise with a specimen for every pupil. If this is not possible, have two students work together. Discussion of this exercise and the text material following it should be done in the laboratory immediately after the exercise.

Individual sketches made by pupils may be compared with Figure 340, page 453, of the text or with a similar enlarged chart. Have pupils examine pollen grains under the microscope.

EXPERIMENT 55. WHAT DIFFERENT PARTS DO SEEDS HAVE? (P. 455). The materials and apparatus needed are:

Lima bean and corn seeds which have been soaked in water for twenty-four hours
Sharp knife or safety razor blades
Hand lens desirable

If safety razor blades are used, secure those with the cutting edge on one side only. If double-edge blades are used, have the pupils wrap all but the tip of the blades in folds of heavy paper or with adhesive tape to prevent cut fingers. The experiment may be used most successfully as an individual exercise with one specimen each of the corn and beans for each pupil. As the dissection is done and the seed parts are laid in rows, allow the use of text material on pages 456-457 for identifying these parts. Help may be necessary with the cross-section of corn in identifying the cotyledon and embryo.

Self-Testing Exercises (p. 458). 1. (*a*) Parts necessary for reproduction: pistil (stigma, style, ovary, ovules), stamens (anthers, pollen).

b) Parts unnecessary: petals, sepals, filament of stamen, receptacle.

2. Steps from production of pollen to formation of seed:

a) Pollen grains escape from anthers.

b) Carried by air or some other means to stigma of pistil.

c) Pollen tube grows from pollen grain and grows down style of pistil.

d) Male, or sperm, nucleus is developing in pollen tube as it grows.

e) Egg nucleus developing at same time in the ovule.

f) Pollen tube grows down to ovule and reaches egg nucleus. Sperm nucleus enters near egg.

g) Sperm and egg unite, i.e., fertilization occurs.

h) Fertilized egg divides and forms new cells.

i) The new cells and the layers of cells around them form a seed.

4. A seed is the embryo, or young plant, plus its nutritive material and protective coverings.

5. The cotyledon of the embryo. Some plants have two cotyledons, and some have only one. On this basis angiosperms are divided into two groups, the monocots and the dicots.

Problems to Solve (p. 459). 1. How seeds are:

Like Spores	*Different from Spores*
a) Produce new plants.	*a*) Contain embryo plant.
b) Have thick coat and contain some stored food.	*b*) Many celled. Spores one- or two-celled.
c) Have some of protoplasm of parent plants.	*c*) Seeds usually result of pollination and fertilization. Many spores produced without fertilization.
d) Aid in dispersal of plants.	

2. Methods of cross-pollination: by wind; by insects; by water; by man; by birds.

Self-Testing Exercises (p. 463). 1. Because they result from the union of material (protoplasm) from both parents.

2. Yes. A male, or sperm, nucleus unites with an egg, or female, nucleus in both flowering plants and animals. In both cases bits of protoplasm from the two parents unite to form a new individual.

3. *Fish.* Fertilization of egg and production of the young occur outside the body of the female.

Bird. Fertilization of the egg occurs within the body of the female. Incubation and hatching of young occur outside the body.

Mammal. Fertilization and development of the young both take place within the body of the female.

4. In the case of birds the eggs must be incubated to keep them warm while cell-division, growth and development take place in the egg. These do not occur if the bird egg is cool.

5. By the fact that the young are not nourished from the milk glands of the mother. Also by having warm bodies and a body-covering of hair (which in a few cases is almost missing). Except in the case of the duck bill and the spiny ant eater, the young are born. However in a number of snakes and fish, the young are born too.

Problems to Solve (p. 463). 2. Bats are not classified as birds, because they have the characteristics of mammals, i.e., they secrete milk for the young, have hair, and bring forth their young alive.

4. There is such a large chance that the eggs will be destroyed in one of many ways, or fail to find the right place for development, that only the production of large numbers of eggs insures the continuation of the species.

PROBLEM 2: HOW DO SEEDS GROW INTO PLANTS? (P. 464)

Plants are the easiest kinds of living things with which pupils can experiment in the laboratory in the study of growth processes. The stages of development from the beginning of the growth of the embryo through the production of seeds can easily be observed, and actual measurements and growth records kept.

The study of the growth of seed plants affords ample opportunity for individual laboratory experiments, field work, and related work in growing plants at home and observing their development. The raising of plants at home as an outgrowth of school work is especially desirable, since it provides a tie-up between school work and real-life situations and provides activities which can be extended throughout the summer in increasing the pupils' pursuit of scientific hobbies.

The teacher and pupils together should plan the work of this problem, with pupil committees assuming the responsibility for providing the various kinds of specimens which are needed. Pupil responsibility for collecting and getting material ready for class use will provide valuable learning situations, which might not be met in other ways.

The main ideas to be stressed during the study of this problem are:

1. Scattering of seeds from the parent plants increases the chances of survival of the species.
2. Seeds have special adaptations which insure scattering.
3. A seed is made up of an embryonic plant and a supply of stored food inside a protective covering.
4. When a seed germinates, water is absorbed and the embryo uses stored food to produce new cells and grow into an independent plant.
5. Roots increase in length by the formation of new cells at the growing point and the elongation of older cells in the region just back of the growing point.
6. Special cells divide to make roots increase in diameter.
7. Root-hairs take in water and dissolved minerals from the soil.
8. Woody stems (of perennials) increase in length by the outgrowth of buds (terminal).
9. Specialized buds produce branches, leaves, and flowers.
10. Stems of woody perennials increase in diameter by the division of the cells in the cambium layer. (The layers added each year by these cells are known as an "annual ring.")

11. The stems of monocotyledonous plants increase in diameter by the increase in the size of the cells (and in young plants by addition of new fibrovascular bundles, which is not stressed in the text).

12. Plants may complete their growth cycles in one growing season (annuals), or in two growing seasons (biennials), or plants may live indefinitely (perennials).

SELF-TESTING EXERCISES (P. 466). 1. (*a*) To avoid competition with the parent plant for sun, water, etc. (*b*) To spread the plant.

2. Ways in which seeds are scattered: carried by animals and man on fur or clothing; in the digestive tract of birds and animals; by the wind; by water; by explosive seed capsules.

EXPERIMENT 56. HOW DO SEEDS GERMINATE? (P. 466). The materials and apparatus needed are:

Bean and corn seeds
Cloth
Two dinner plates
Small pots of earth

Start the seeds at least five days before they will be needed for use in this experiment. Direct observations toward the parts of embryo which first grow out of the seed, the increase of size in the embryo, the number and behavior of cotyledons, the rate of growth, and the appearance of foliage leaves. Have the pupils make sketches (similar to Figure 350, page 467) from actual specimens to show the growth of seedlings.

An interesting way of handling part *b* of the experiment is to plant one seed every three days against the glass in a box with a glass front. Because of the glass front the different stages of growth of the seedling can be observed without disturbing the roots.

EXPERIMENT 57. HOW DO STEMS GROW LONGER? (P. 469). The materials and apparatus needed are:

Shoots of ash, buckeye, horse-chestnut, and other trees before the shoots have leafed out
Knife

Have the pupils use the text material and Figure 352, page 469, for identifying the parts of the shoots. Lenticels or "breathing pores" and leaf scars may also be located on the specimens. Be sure that each pupil can identify each year's growth on his specimen and tell the entire age of the shoot. The terminal bud will contain an embryonic branch. If these buds are well matured, then the embryonic branches will show up plainly in longitudinal sections. Put some of the shoots in water and watch the terminal and other buds develop.

EXPERIMENT 58. HOW DO THE STEMS OF TREES GROW IN THICKNESS? (P. 470). The materials and apparatus needed are:

Sharp knife

Tree branch approximately one inch in diameter

Tree branch approximately one-half inch in diameter

Tree stump which may be examined, or specimens of cross-sections of tree limbs or small trunks at least six inches in diameter

a) Layers or rings will be visible in specimens which are properly cut. The soft cambium layer is the place where the bark pulls away from the wood.

b) The number of layers or rings will usually be less than for specimen used in part *a*.

c) The heart-wood, sap-wood, and annual rings can be easily distinguished. The cambium region may not show up well. Have the pupils estimate the age of the specimens by counting the annual rings. Be sure to note that each ring consists of two parts: the lighter colored, larger-celled spring growth, and the more compact darker-appearing summer growth.

A good way of making a permanent collection of cross-sections for class study is to have sections cut from large tree limbs or small tree trunks. When these specimens have dried out, have one end of each section sandpapered and shellacked. The structures in such specimens usually show up clearly. Heavy rays radiating outward from the center are wood rays.

SELF-TESTING EXERCISES (P. 472). 2. (a) The root cap is a group of cells that grows over the root tip. The root tip contains the growing point, that is, the actively growing cells that form the new root cap cells as well as the other cells of the root.

b) The root cap protects the cells of the root tip as it pushes through the soil.

3. In transplanting plants you will know that you must be careful: (a) not to break off the root tips if you want the roots to continue growth.

b) Not to break off the root-hairs so that the plant cannot take in water.

c) In watering trees you must water at a distance from the tree, where the young roots and root-hairs are.

4. Under the different growing conditions of different times of year different-sized cells are formed. The cells formed in the spring are larger than those formed in the summer and the rings of wood formed in the two seasons appear to be of different colors.

5. By cell divisions that take place in the growing point, or tip, of the stem and by increase in length of the cells back of the growing point.

6. By counting the spaces between the bud-scale scars.

PROBLEMS TO SOLVE (P. 472). 1. Because the root-hairs have been torn off or damaged. The plant cannot take in water until new ones have grown. This could be prevented by digging up the soil with the roots. The plant may also wilt because the soil is so loosely packed about the roots that the root-hairs are not in contact with soil particles from which to obtain moisture. If water is poured into the soil so that it is muddy, it can be packed closer to the root-hairs.

2. No. Trees increase in height only at the tip, and a nail driven into the trunk of a tree remains at the same height above the ground.

SELF-TESTING EXERCISES (P. 474). 1. Diagram should include all stages of development: seed, germinating seed, young plant, mature plants with flowers and with fruit containing seeds.

2. *Annual:* plant that completes its life cycle in one year.
Biennial: plant that requires two years to complete its life cycle.
Perennial: plant that lives more than two years.

PROBLEMS TO SOLVE (P. 474). 1. Answers will vary with type and location of community.

2. Answers will vary with community. In most cases will probably be a tree of some kind.

PROBLEM 3: HOW DO ANIMALS GROW? (P. 474)

Pupils are likely to exhibit much interest in this problem because it deals with living things which exhibit striking changes in their growth processes. Also the young of animals make a decided appeal in their appearance and movement. The study of the growth of human beings should help make the material vital to the pupils.

The important ideas to be stressed during the study of this problem are:

1. Higher animals develop from special cells known as eggs.
2. Animal embryos develop from the egg cell by means of cell-division, differentiation and specialization of cells, and growth in a definite series of stages.
3. The processes of development are much the same for all vertebrates whether they take a short or long time to develop, whether they develop in an egg or in the body of the mother.
4. Many lower animals undergo a complete change of bodily form from the time the young are hatched until they become adults.
5. The length of time required for incubation or gestation varies greatly for different kinds of animals.

EXPERIMENT 59. WHAT HAPPENS TO AN EGG AS IT DEVELOPS INTO A CHICKEN? (P. 475). Materials and apparatus needed are:

Fertile eggs (one dozen or more)
Incubator (or hen and nesting material for hen)

This experiment may seem difficult, but in all cases the interest and enthusiasm it arouses in the pupils make it well worth while. City children in particular will enjoy observing a hen incubate the eggs. Some of the eggs should be allowed to hatch, and the pupils should care for the hen and chicks for a short period of time. The use of an incubator will be the most practicable method of incubation in most cases however. An inexpensive electric incubator can probably be obtained from one of the mail-order houses, or a satisfactory substitute can be made. Helpful suggestions for carrying out this project successfully can be found in the following articles: Price, John W. and Fowler, Ernest V., "Eggshell Caps—A Method of Rearing Chick Embryos Visible Throughout Incubation." *Amer. Biol. Teacher,* October 1940, pp. 23-24, and Miller, Lula A. "Hatching Chickens in a Laboratory" on page 25 of the same magazine.

Pupils should examine the developing chick embryos with a strong hand lens. Usually the beating of the heart and circulation of the blood are easily seen at the proper stages. Have the pupils keep careful sketches and notes to show the day to day development of the embryo. The early stages of cell division (as shown in Figure 358, page 476) cannot be seen without the use of difficult laboratory techniques.

SELF-TESTING EXERCISES (P. 481). 3. Vertebrate animals that lay eggs are oviparous. Vertebrate animals that give birth to living young are viviparous. Examples will vary with community, but almost any community will include: (a) *Oviparous:* wild birds, domestic fowl: chickens, ducks, etc., some snakes, frogs, fish (most), turtles.
b) *Viviparous:* dogs, cats, horses, cows, pigs, mice, rats, some fish such as guppies, some snakes.

4. Different periods in life cycle of human being:

PERIOD	APPEARANCE	WHAT INDIVIDUAL CAN DO
Infancy	Small, little hair, no teeth at first.	Helpless. Can't walk, talk, etc.
Childhood	Growing tall; new teeth; hair. Shape of face changed to oval.	Walk, talk, do various things that they learn at this time.
Adolescence	Still growing.	Can read and do more difficult things.
Adult	Stop growing when mature.	Full mental and physical abilities.
Old age	Hair becomes gray or white. Becomes wrinkled and stooped.	Less active.

5. The flexible substance known as cartilage is replaced by bone as child grows older.

PROBLEMS TO SOLVE (P. 481). 1. (Suggestions are given as to different types of likenesses and differences.)

How like parents	*How different from parents*
General shape	Size; proportion of parts
Organs possessed	Play activity
Color	Amount of time spent in rest and sleep
Way of moving around	Dependence on others

EXPERIMENT 60. HOW DO FROGS DEVELOP? (P. 482). The materials and apparatus needed are:

Frog or salamander eggs

Aquarium with plants (or shallow dishes in which water may be changed frequently)

Hand lens

Collect the egg masses in the early spring on field trips taken with the pupils. (They may be ordered from biological supply companies.) Have the pupils observe the eggs with hand lenses and make careful notes and sketches to show the development of the eggs. The tadpoles may be raised until they have reached the frog stage. Technique for observing the early stages of cell development will be too difficult for the pupils to do.

SELF-TESTING EXERCISES (P. 486). 1. Stages frogs go through as they grow from egg to frog. (*a*) egg; (*b*) egg divides to form embryo; (*c*) embryo develops into tadpole; (*d*) tadpole develops; hind legs grow and tail is lost; air-breathing lungs develop; front legs appear; (*e*) frog.

2. It is still living on a part of the egg material that is left in its body. (The mouth is not yet open.)

3. Metamorphosis means change of form, such as the series of changes that certain animals go through as they are developing.

4. Metamorphosis of:

FROG	MOTH	GRASSHOPPER
Egg	Egg	Egg
Tadpole	Larva	Early nymph
Frog	Pupa	Late nymph
	Adult	Adult

PROBLEMS TO SOLVE (P. 486). 1. Yes. Adult frogs have air-breathing lungs instead of gills and must come up to the surface of the water to breathe except when they are hibernating.

2. It means the same in the sense that both grasshopper and chicken shed something. But in the case of the chicken it means shedding some feathers and replacing them. In the grasshopper, however, it means shedding a whole covering and replacing it with a new one.

3. Lists will vary with different communities.

LOOKING BACK AT UNIT 10 (P. 487). 1. Answers will of course vary, but should include these ideas:

PROBLEM 1: *What is the simplest way in which plants and animals reproduce?* The simplest way in which animals and plants reproduce is by dividing. A one-celled animal or plant separates into two parts with half the nucleus and protoplasm in each part. This is repeated again and again.

How do spores help plants reproduce? Spores are small cells that can start new plants. One plant can produce thousands of spores, each of which will grow into a new plant if conditions are right.

How do plants reproduce from parts of their bodies? By a process called regeneration part of a plant may grow all the parts of the plant that are missing. Underground stems called rhizomes and runners called stolons also grow new plants at places called nodes.

How do plants make seeds? Seed plants have male parts (stamens) and female parts (pistils). Sometimes these parts are on the same plants, and sometimes they are on separate plants. Pollen from the stamen fertilizes the egg cell in the pistil. Two cells unite to form one new cell. The fertilized egg cell divides and develops into a tiny plant which is later to be found inside a seed.

How do higher animals reproduce? A sperm cell from the male unites with an egg cell of the female to form a new individual. The fertilized egg cell sometimes develops in the body or sometimes outside the body of the female.

PROBLEM 2: *How are seeds scattered?* Seeds are scattered by being carried by the wind, by animals and man on fur or clothing, in the digestive tracts of animals and birds, by moving water, by bursting violently from seed pods.

How do seeds grow into new plants? Mature seeds are scattered and then usually lie dormant until the growing season begins. Then germination takes place. The embryo grows, using the food stored in the seed. Cells divide, and roots and stems are pushed out. Leaves grow and soon the plant can make its own food.

How does a plant increase in size? Plants increase in size by the growth of new cells and also by the growth of old cells. Roots and stems grow at the tips by adding new cells. They grow larger around when old cells grow larger, or in the case of certain kinds of plants, when layers of new cells are added to the stem inside the outer bark.

How long do plants live? Some plants (annuals) live only one season, during which they complete their life cycle. Other plants (biennials) require two growing seasons to complete their life cycle. Still others (perennials) live more than two years.

PROBLEM 3: *How does a chicken grow?* The fertilized egg divides again and again with the cells grouped in a ball. Layers of cells develop. From these layers different parts of the body develop. The embryo uses the food material in the egg to grow.

How do animals develop by metamorphosis? Some animals go through changes in form (metamorphosis) as they develop. During the different stages of growth the young animal does not always resemble the adult. In fact, in some animals the appearance is entirely different.

2. *Reproduction* is the process by which new living things are created.

A *spore* is a single cell that can grow into a new plant.

An *egg* is a female reproductive cell.

An *embryo* is an animal or plant in the earlier stages of its development, or before birth or germination.

Perennials are plants that live more than two years.

An *ovary* is an organ of a female animal in which eggs are produced or the part of a plant that encloses the young seeds.

The *life cycle* includes all the stages in the life of an organism from fertilized egg to adult.

The *mycelium* is the mass of thread-like material forming part of a fungus.

Fertilization is the uniting of the nuclei of male and female reproductive cells.

Dicotyledonous plants have embryos with two cotyledons (embryo leaves).

Germination is the beginning of growth in a pollen grain or a seed.

The *pistil* is the female reproductive part of a seed plant.

Regeneration is the process by which some plants and animals can grow missing parts from one part.

Metamorphosis is change of form during growth from immaturity to adulthood.

Fission is reproduction by means of cell division in one-celled plants and animals.

A *seed* is a special structure developed in certain kinds of plants (seed plants), that contains and protects each embryo plant.

A *sperm* is a male reproductive cell.

Birds *incubate* their eggs when they sit on the eggs to keep them warm until they hatch.

Biennials are plants that require two growing seasons to complete their life cycle.

A *pupa* is the stage of an insect that follows a larva. It is often enclosed in a special case.

The *cambium* is the layer of delicate growing cells between the wood and bark in trees and shrubs.

ADDITIONAL EXERCISES (P. 487). 2. Would suggest making some spore prints on black paper. Most of them show up better that way.

7. The root system of the corn is very extensive, and the roots go out about three feet laterally as well as several feet deep if the soil permits. If the plants are too close together, the roots are crowded and there is not enough moisture to supply the root systems of all the plants.

BULLETINS AND PAMPHLETS FOR UNIT 10

Farmers' Bulletin 1567. *Propagation of Trees and Shrubs.* 5c

Fisheries Bulletin 31. *Natural History and Method of Controlling Starfish.* 20c

General Biological Supply House. Turtox Service Leaflets. (free to teachers on request)

No. 16. *The Culture of Planaria and Its Use in Regeneration Experiments.*

No. 34. *How to Maintain Living Material in the Laboratory to Demonstrate Different Types of Insect Life.*

VISUAL MATERIAL

MOTION PICTURES

Encyclopaedia Britannica Films

"Mold and Yeast"
"Fungus Plants"
"Plant Growth"
"Flowers at Work"
"Frogs, Toads, and Salamanders"
"Wild Flowers"
"Seed Dispersal"
"The Frog"
"Butterflies"
"The Development of a Bird Embryo"
"From Flower to Fruit"

Society for Visual Education
"Life History of the Monarch Butterfly"

FILMSTRIPS

General Biological Supply House
"Life History of Frog"

Society for Visual Education
"Some Insect Life Histories"

CHARTS

Ralston Purina Co., St. Louis, Mo.
Longitudinal Section of a Grain of Wheat. Wall chart 24 × 39 (free)

United States Office of Education (Extension Service)
Educational Illustrations. Group 10. Includes chart showing structure of corn kernel. 15 × 12 in. 15c per set of 7 charts.

UNIT 11

How Do We Take Care of the Plants and Animals We Use?

FUNCTION AND SCOPE OF UNIT 11. Up to this point in the series, the text matter dealing with living things has been concerned with their major life processes and activities. Units 8, 9, and 11 of *Book 1* and Unit 10 of *Book 2* provide a background of biological principles and concepts for understanding the use man makes of this knowledge in fostering his own welfare.

Of the fields of activity that deal almost exclusively with plants and animals, farming is most widespread and important. Thus it forms the core of the unit and furnishes most of the illustrative material. The ideas developed apply equally well to any similar activity in which boys and girls may be interested such as gardening, lawn care, raising of pets or poultry.

The unit begins with a consideration of the soil which is the "foundation" of the farm. It next considers the organisms that compete with the farmer and his plants and animals and the diseases he must control. Third, it takes up the problem of scientific feeding, and finally the protection of animals and growing plants from the dangers of weather and climate. See the graph for Unit 11 on page 248.

This unit occurs at the end of the book for two reasons (*a*) to allow for developing as much of the background as possible and (*b*) to have the unit come in the spring when farming activities and weather are favorable for observations of farming.

This unit will be much more fully understood if pupils have a background of certain ideas which have been treated earlier in the course. In case the class has not had an opportunity to study each of the units mentioned below the teacher may need to put some special emphasis on the ideas that are new.

Book 1

Unit 5. Chemical elements.

Unit 10. Different kinds of foods and their value to the body.

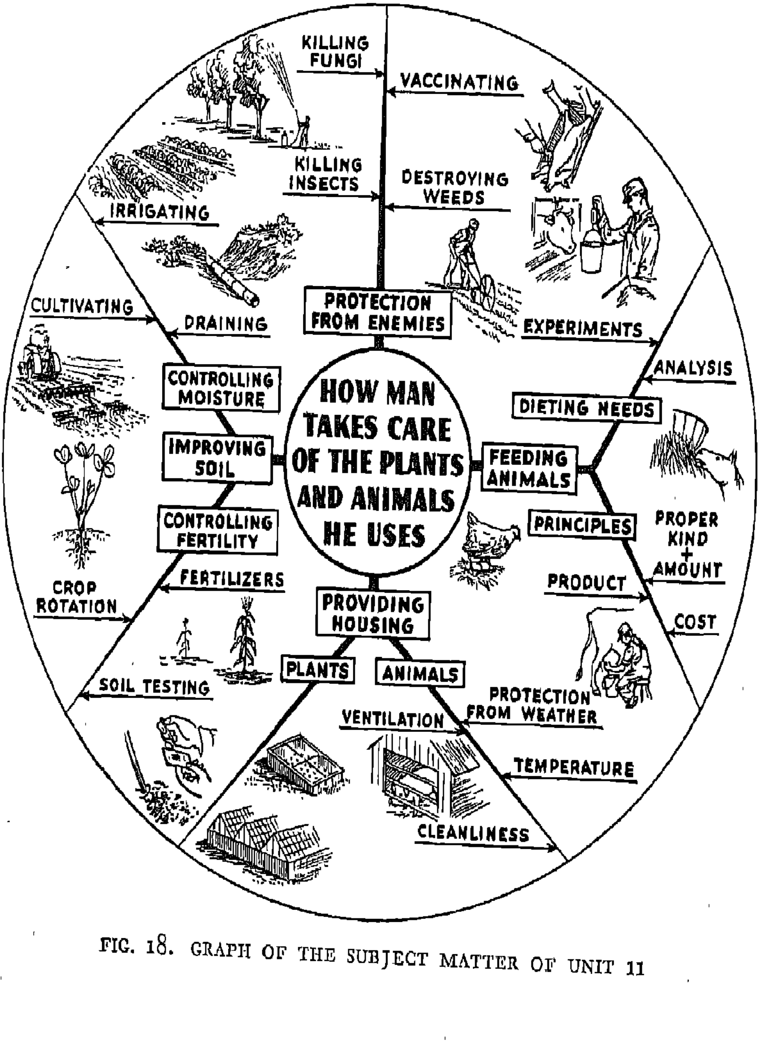

FIG. 18. GRAPH OF THE SUBJECT MATTER OF UNIT 11

Book 2

Unit 3. How rocks are changed into soil.

Unit 6. (a) How heat travels.

b) How we keep buildings warm.

Unit 9. (a) How immunity to disease can be developed.

b) How we can prevent the spread of disease germs.

Unit 10. (a) Reproduction of fungi by spores.

b) Life cycle of insects.

INTRODUCTORY EXERCISES (P. 490). 1. (a) Enough water to keep them supplied with water and minerals, but not enough to cut off supply of oxygen from roots.

b) Soil that is of proper consistency to hold moisture but that does not hold too much nor pack so that the oxygen supply is cut off.

c) Soil having plentiful supply of necessary minerals.

d) Plenty of air and sunlight to provide proper conditions for photosynthesis to occur.

e) Proper temperature conditions.

2. Rock and decayed organic matter.

3, and 4. Care of corn crop:

a) Plow the soil.

Old Way: Plowing a single furrow at a time with a hand or horse plow.

New Way: Plowing two or more furrows at a time with a gang plow.

b) Add fertilizer if necessary.

Old Way: Scattered by hand or by pitchfork if using manure.

New Way: Using a fertilizer or manure spreader.

c) Cultivate field to break soil up into smaller pieces.

Old Way: 2-horse cultivator.

New Way: Four or more horses or tractor pulling various harrows.

d) Plant corn.

Old Way: Dropped into hills and covered by hand.

New Way: Planted with corn planter. Rows corn in both directions, two rows or more at once.

e) Cultivate young corn.

Old Way: By hand.

New Way: Two-row cultivators.

f) Harvest corn.

Old Way: For grain, husked by hand; for silage, cut by hand.

New Way: For grain, power huskers beginning to be used. Tractor with two-row corn picker. For silage, cut by corn binder.

g) Store corn.

Old Way: For grain, ears are shoveled from wagon to crib.

New Way: Grain: Many farmers now have elevators for putting corn in crib. Silage: Power machine prepares silage and puts it into silo. May be made into silage as cut in field.

*5. The series of events in which the elements and compounds in the soil and air are used as food by plants and animals and returned to the soil and air.

*6. Plants, such as beans, soybeans, peas, clover, alfalfa, that belong to a certain plant group. They help other plants by means of the bacteria that grow in tubercles on their roots. These bacteria can take nitrogen from the air and change it into a form usable by plants. Thus they add to the supply of nitrogen compounds in the soil.

7. Crop rotation means growing a series of two or more crops before growing the first again. The series should always include a crop that adds nitrogen to the soil. For example, instead of planting a field of corn year after year, a farmer plants corn then wheat and then clover. When the clover is cut the roots remain in the soil and add nitrogen compounds to the soil.

10. A greenhouse has a heating plant that keeps the temperature right for the best growth. The glass roof and walls keep the warm air in and admit the light needed by the plants. Water is provided by sprinkling.

A hot-bed is kept warm by decaying manure on which the soil of the bed is placed. Other conditions are maintained as in the greenhouse.

11. A dairy barn or a poultry house should provide: (*a*) sufficient sun and air; (*b*) a way of being cleansed readily; (*c*) a clean water supply; (*d*) freedom from contamination with disease germs.

LOOKING AHEAD TO UNIT 11 (P. 491). The purpose of this section is to give the pupils an idea of the kinds of tasks required of the farmer, the kinds of problems he must solve, and the necessity of using the results obtained by scientists to help solve his problems. If there are pupils in the class who have lived on farms, they might be asked to tell what their fathers or the farmers did during the course of one day. They should also be asked to supplement the list of problems raised in this section and to cite examples to show how their parents have used federal or state assistance in solving their problems.

PROBLEM 1: HOW DO FARMERS IMPROVE THEIR SOIL? (P. 495)

The pupils have already studied the composition of the soil in Unit 3, and they have learned what the requirements are for plant growth. This problem is concerned with the methods of preparing and treating the soil so as to secure the best conditions for plant growth. The problem may be introduced by raising the question, "What have you seen farmers or gardeners do to their soil?" Then pupils may be asked to tell what effect on the soil was produced by each of the things the farmer or gardener did. The main ideas of the problem are:

1. To have the correct supply of moisture in soil is one of the great problems of farmers.
2. Soil with the correct amount of moisture has a very thin film of moisture around each particle.
3. As plants take water out of the soil that touches their roots, water from moister regions moves in by capillary action. Water moves best in this way in fine, closely packed soil.
4. In very dry regions water is often brought in for irrigation of the land.
5. Where there is limited rainfall, farmers carry on "dry farming" by leaving the soil idle, but cultivated, every second or third year.
6. Soil that stays wet too long can often be improved by draining it off through open ditches or tile pipes.
7. Good farmers keep their soil fertile (*a*) by returning much plant material to it, (*b*) by rotating crops, and (*c*) by careful use of commercial fertilizers containing nitrogen, phosphorus, potassium, and lime.

EXPERIMENT 61. HOW DOES SOIL BEHAVE WHEN IT CONTAINS DIFFERENT AMOUNTS OF MOISTURE? (P. 496). The sample of soil should have been obtained at least a week before the experiment and stored in a warm dry place in a shallow, open box. The soil that will just stick together is the best soil for plant growth.

EXPERIMENT 62. HOW IS THE GROWTH OF PLANTS RELATED TO THE AMOUNT OF WATER IN THE SOIL? (P. 496). The materials and apparatus needed are:

3 to 10 pint cans
Nail for punching holes
Soil
Corn seeds

The experiment should show that plants grow slowly, if at all, in saturated soil and that there is a certain amount of moisture which produces the best results in growing plants. To get more accurate results, use ten cans. Pour one tablespoonful of water in Can 1, two tablespoonfuls in Can 2, etc.

EXPERIMENT 63. HOW DOES WATER MOVE TOWARD PLANT ROOTS? (P. 499). The apparatus and materials needed are:

2 saucers
2 lamp wicks or strips of towel paper
Capillary tubes (different sizes)
1 or more lamp chimneys
Cloth for end of chimney

a) A strip of towel paper, several layers thick, may be used instead of lamp wicks.
b) The physics laboratory can probably supply a set of capillary tubes of various sizes. The law of capillary action is that the smaller the diameter of the tube, the higher the liquid is raised.
c) If different kinds of soil are used in different chimneys, it is easy to show that the rate at which water moves upward through the soil varies with the kind of soil.

SELF-TESTING EXERCISES (P. 500). 1. When soil has just the right amount of water in it the plant roots can get enough water and minerals, and air can also reach the roots. Otherwise the plants will not grow well.

2. In saturated soil the water is held in the spaces between the particles. In moist soil the water is held in a thin film around each particle.

3. It enables rain water that has soaked into the ground below the plant roots to rise up through the soil to the point where it is available to the roots after they have used that near them.

SELF-TESTING EXERCISES (P. 504). 1. It makes large spaces between the lumps of soil; these large spaces keep the water from rising by capillary action and being lost from the soil by evaporation.

2. Dry farming means using all possible methods of conserving the moisture in the soil. These include keeping the top soil loose and broken up and letting each field be idle but cultivated for one out of every two or three years.

3. Ways of controlling amounts of water in soil: (*a*) cultivating soil; (*b*) irrigating; (*c*) dry farming; (*d*) draining soil through open ditches or tile pipes.

PROBLEMS TO SOLVE (P. 504). 1. Tile drainage. (*a*) *Advantages.* (*1*) Prevents soil erosion. (*2*) Wet soils can be cultivated earlier.

b) *Disadvantage.* Expensive.

2. Some disadvantages of open ditches. (*a*) Provide places for soil erosion. (*b*) Weeds grow in them and become centers of distribution for weeds. (*c*) Water in them may be breeding-places for mosquitoes. (*d*) Take up room needed for growing crops. (*e*) Interfere with cultivation of crops.

SELF-TESTING EXERCISES (P. 510). 1. (*a*) Same minerals are taken from soil each year. (*b*) It is thought that roots of each kind of crop give off substances that accumulate in the soil and interfere with the growth of that kind of plant the next year.

2. To increase supply of nitrogen and other minerals in soil and to add humus. The plant materials and manure decay and return the minerals to the soil, to be used by other plants.

3. Crop rotation means planting a different crop on a field each year or every two or three years.—For example, corn one year, wheat or oats the next year, and then clover or soybeans the third year. The fourth year corn may be planted again.

4. They have nitrogen-fixing bacteria in nodules or tubercles on their roots. These bacteria can take pure nitrogen from the air

and change it into nitrogen compounds that can dissolve in soil water and be used by the plants. When the plants die or are cut, the whole plant or the root systems are plowed into the soil, and the nitrogen is added to the soil.

5. (a) Sends samples of soil to an experiment station for testing.
b) Tests soil with a soil-testing kit.
c) Carefully observes growing crops, if he knows the symptoms of various mineral deficiencies. (Many good farmers decide on the basis of past experience of themselves and others in the use of different fertilizers, or ask the advice of the county agricultural agent.)

6. (a) By using good drainage, which carries away acids added to the soil by plant roots.
b) By using lime or ground limestone, which changes acids to minerals that do not harm plants.

PROBLEMS TO SOLVE (P. 511). 1-6. All are research or activity exercises.

PROBLEM 2: HOW DO WE PROTECT OUR PLANTS AND ANIMALS FROM THEIR NATURAL ENEMIES? (P. 512)

This problem is concerned with man's methods of combating the three major menaces to his domestic plants and animals—weeds, insects, and disease. The following main ideas are presented:

1. Farmers constantly fight weeds by cultivating crops, planting weed-free seeds, and destroying the undesirable plants in every practical way.
2. Farmers constantly fight insect enemies of plants and animals by cultivation, crop rotation, quarantine, and poison, and by encouraging the birds and other natural enemies of the harmful insects.
3. Fungus enemies of plants are kept under control by growing resistant varieties of crops, by destroying other plants on which the fungi must live, by sterilizing the soil, by treating seeds and growing plants with chemicals, and by rotating the crop plants.

4. Diseases and parasites of animals are kept under control by vaccination, destruction of sick animals, use of insecticides, and general sanitation.

SELF-TESTING EXERCISES (P. 514). 1. (a) Weeds use water and minerals needed by crops.
b) Weeds compete with crops for light needed to make food.
c) Weed seeds mixed with grain and hay reduce the prices farmers can get for crops.

2. "Purity of seeds" means the percentage of seeds in a given package that are not weed seeds.

3. (a) Cultivate soil thoroughly and regularly. Keeps plants from maturing and producing seed.
b) Use pure seeds from reliable companies. Keeps weed seeds out of crops.
c) Pasture land with hogs, cattle, sheep, or goats. Animals eat weeds before seeds are produced.
d) Use chemicals, such as salt, oil, or iron sulphate. Kills weeds.
e) Burn weeds. Kills weeds.
f) Rotate crops. Use of a crop that grows thickly will not give the weeds a good opportunity to grow.

PROBLEMS TO SOLVE (P. 514). 2. In early summer when the weeds are tall enough to be mowed but have not yet flowered and produced seed.

SELF-TESTING EXERCISES (P. 521). 1. Reasons to be included.
a) Method of control often depends on knowing at what times of year the insect is in its different stages of development.
b) Habits of different stages of development vary, and control may depend on knowing these.
c) Must know which stage is the harmful stage.
d) Knowing how they reproduce may enable scientists to prevent production of great numbers of insects.

2. (a) Burning wild plants in late autumn and early spring.
b) Planting crops early or late.
c) Thorough cultivating of soil.
d) Rotating crops.
e) Using poisonous chemicals

f) Quarantine.
g) Putting sticky bands of paper around tree trunks.
h) Protecting and encouraging birds.
i) Use of predaceous insects.

3. Insects that prey upon other insects. Examples: Australian and other kinds of ladybird beetles; European ground beetle.

PROBLEMS TO SOLVE (P. 521). 1-5. All answers will vary, as they depend on the community or some individual activity.

SELF-TESTING EXERCISES (P. 524). 1. (*a*) *Grow plants that resist disease.* Some varieties resist disease better than others. Farmers select and plant these. Fungi do not injure them.
b) *Destroy plants on which disease germ spends part of life.* If organism such as wheat rust fungus, lives part of life on other plant (barberry bush), destroy other plant. This makes it impossible for fungus to complete life cycle.
c) *Use chemicals in soil.* Chemicals, such as sulphur for potato scab, will help kill organism in soil.
d) *Heat soil.* Burning piles of tree branches kills fungi in soil that attack plants.
e) *Treat seeds with chemicals before planting.* Chemicals kill spores or other organisms sticking to seeds.
f) *Rotate crops.* Sometimes germs cannot live unless they can get food from certain crop grown every year. Planting different crop removes food supply of germs.

2. See part a of Exercise 1.
3. See part *f* of Exercise 1.

PROBLEMS TO SOLVE (P. 525). 2. Answer will vary. It is believed that in cold climates one stage of the life cycle of the wheat rust usually must be passed on the barberry in the early spring. If no barberry bushes are available the rust cannot then get started growing in the spring.

SELF-TESTING EXERCISES (P. 528). 1. Answers will vary, but may include: (*a*) Vaccination of dogs against rabies.
b) Vaccination of hogs against cholera.
c) Treatment of cattle and sheep with chemicals to rid them of ticks.

d) Dusting chickens with insecticide to kill lice.

e) Tuberculin test for cows to prevent spread of tuberculosis from diseased animals.

f) Clean living quarters.

2. (a) *Serum*, as used in the prevention and cure of disease, is the clear liquid from the blood of animals that have had a certain disease. It contains antibodies made by the body to help fight the disease.

b) *Virus* is the germ or cause of a certain disease (such as hog cholera).

c) Serum alone is used for single vaccination when an outbreak of disease (cholera) is already started in a herd. To prevent a disease (cholera) from getting into a herd, both serum and virus are used. This makes the animals (hogs) immune for a longer time.

3. (a) *Mites*. By keeping the chicken house thoroughly cleaned with insecticide, making certain that the solution penetrates the cracks. Whitewash carefully to fill in the cracks where mites usually hide.

b) *Lice*. By dusting their feathers thoroughly with sodium fluoride powder.

PROBLEMS TO SOLVE (P. 528). 1, 2. Answers will vary, as these depend on trips and reports.

PROBLEM 3: HOW DO WE SELECT FOOD FOR OUR ANIMALS? (P. 529)

The main idea to be stressed in this problem is that different animals have different food requirements and that it is essential to provide the proper kinds of food for healthy growth or for the animal product desired. Pupils might be asked to list the kinds of food that are fed to different kinds of pets. The kind of food should then be related to the type of structure of the animal. The main ideas are as follows:

1. Food for animals must contain the same kinds of materials as food for human beings.
2. These materials must be contained in food that each particular kind of animal can eat and digest.

3. The materials must be provided in the correct proportion and amounts for the needs of the animal's own life and for its special product.

4. Food must be provided at the lowest possible cost.

5. Scientific experimenters provide farmers with much helpful information about feeding animals.

SELF-TESTING EXERCISES (P. 533). 1. Yes. Farm animals need fats, proteins, carbohydrates, vitamins, etc., in their diets, just as human beings do. Their food must be selected to give them these things in the proper proportions according to the particular kind of animal. People, too, vary in their requirements for the different foods.

2. (a) Feed animals kind and proper proportion of food substances found in animals' bodies. *Example:* Consult tables for correct nutritive ratio for dairy cows.

b) Feed animals kinds of foods they can digest. *Example:* Timothy hay for horses—not for hogs.

c) Animals must have proper combination and amount of roughage. *Example:* Do not feed horses all corn or all hay.

d) Food must provide for making new tissues and producing energy needed by animals. *Example:* Consult tables for amount to feed dairy cow of certain weight.

e) Animals' food must furnish proper materials to make product we need. Different kinds of foods produce different effects on animals' bodies. *Example:* Consult tables for dairy cow giving certain amount of milk.

f) We must consider cost and select kinds of food that will get the best results for least possible cost. *Example:* Feed clover hay if there is plenty at low cost rather than alfalfa that is better but expensive.

3. Only by making experiments and keeping careful records of results can we be sure that accurate conclusions about the best ways to feed animals can be reached.

4. (a) Find out in general what kinds of food chickens can eat and digest.

b) Decide whether they are being raised for meat or for eggs.

c) Find out what kinds of food are best for the result you desire.

d) Find out the proportions of foods for chickens of certain weights.

PROBLEMS TO SOLVE (P. 534). 3. Kinds of food for different farm animals from information based on U. S. D. A. Farmers' Bulletins:

ANIMAL	FOOD GIVEN	REASON GIVEN
Horse	Hay (various kinds)	
	Alfalfa	Roughage, protein, minerals
	Clover	Protein content; minerals
	Timothy	Protein
		Roughage
	Grains—oats, corn, etc.	Carbohydrates, energy foods
Cow	Pasture grass	Roughage, minerals, vitamin-A content, water
	Hays—alfalfa best	Roughage, proteins, minerals
	Silage	Vitamin A, minerals
	Grains	Carbohydrates
Pig	Forage—rye, blue-grass, alfalfa, rape, oats	Fattening
		Energy
	Grains—corn (best), oats, wheat, barley	Fattening and energy
	Grain substitutes — potatoes, molasses, garbage	Same
	Protein supplement—tankage, fish meal, soy beans, cotton-seed meal	Supply protein needed for growth
	Alfalfa	Proteins
	Milk products	Proteins and vitamins
	Minerals—salt, lime, phosphates, bone meal, meat meal	Growth of skeleton and tissues
Chickens		
For meat:	Corn meal, oat meal	Fattening for market
For eggs:	Scratch feed—corn, wheat, oats	Carbohydrates, to give exercise as scratch and pick-up grain
	Mash—corn meal, ground oats, wheat, meat scrap	Carbohydrates, proteins, and minerals
	Meat feed, milk	To supply extra proteins needed
	Oyster shell, clam shell, limestone	To supply calcium for egg shell formation
	Grit	To keep gizzard in good condition for digesting food to best advantage

ANIMAL	FOOD GIVEN	REASON GIVEN
Duck	Mash made of:	
	Corn meal	Fattening, energy
	Bran	Roughage
	Low-grade wheat	Energy, proteins
	Beef scrap	Proteins
	Grit	Keep gizzard in good condition
	Oyster shell, bone ash, bone meal	Minerals
	Green feed—cut alfalfa, clover, rye, oats, corn	Proteins, vitamins

PROBLEM 4: HOW DO WE PROVIDE PROPER HOUSING FOR OUR ANIMALS AND PLANTS? (P. 535)

This problem emphasizes the idea that proper living conditions are required to raise healthy, vigorous plants and animals. A field trip to a modern farm, if possible, is the best source of material. The pupils should study the text before taking the trip, so that they will have a better basis for their observations. The main ideas are:

1. Young plants are started early in the spring in glass-protected beds; sometimes these beds are heated by allowing manure to decay beneath them.

2. Animal quarters should be built to be dry, comfortably warm for the animals, well-ventilated, and sanitary. The practical details are different for each different kind of animal.

SELF-TESTING EXERCISES (P. 538). 1. (*a*) Heat is given out when chemical changes take place. Bacteria bring about a chemical change in the manure in the hotbed. This chemical change produces heat and keeps the soil warm.

b) Radiant energy passes through glass and is absorbed and changed by soil to heat.

2. (*a*) No manure to decay and keep soil warm, or steam pipes for same purpose.

b) Uses: (*1*) To harden tender plants that have been started in hotbeds; (*2*) To start plants so that they will mature early, and ripen before they can be attacked by insect enemies. Also vegetables bring higher prices in early spring.

PROBLEMS TO SOLVE (P. 538). 1. Possible answers are: (a) greenhouses, hotbeds; (b) grain elevators, root cellars, storehouses, barns, granaries.

2. The kinds of plants vary with region, when wanted for use, etc.

HOTBEDS	COLD-FRAMES	GREENHOUSES
Radishes (for forcing)	Spinach, lettuce (winter over)	Radishes (for forcing)
Tomatoes	Cabbage	Tomatoes
Spinach	Snapdragons	Cabbage
Eggplant	Cosmos	Beets
Snapdragons	Larkspur	Lettuce
Cosmos	Marigolds	Eggplants
Larkspur	Pansies (winter over)	
Marigolds		
Petunias	Petunias	
Hollyhocks	Hollyhocks	

3. (a) Orchards are planted where frost is least apt to form.
b) Orchardists build smudge fires when frost threatens.
c) Corn is planted to mature before frost.

SELF-TESTING EXERCISES (P. 544). 1. Temperature of 55°-65° is best for most farm animals. This is lower than the temperature required for people. Animals are used to staying out of doors much of the time, and higher temperatures would be harmful.

2. (a) Concrete floors in barn.
b) Individual stall for each cow.
c) Four hundred cubic feet or more of space for each cow.
d) Three square feet of window glass for each cow.
e) Controlled ventilation.
f) Water troughs in each stall.

3. (a) Chickens have high body temperature and breathe faster than human beings.
b) Must have plenty of sunlight in order to keep bodies in good condition and to give eggs thick shells and make them hatch.
c) Suffer more from cold when air is damp.

4. (a) Movable houses to keep hogs free from disease.
b) Rail around inside of house to keep hog from lying on pigs.
c) Small door to let small pigs in and out when mother must be kept in.

Problems to Solve (p. 545). 2. (a) *Differences:* (*1*) Do not need so much ventilation or light. (2) No excretion to dispose of. (3) No feeding necessary. (4) Different means of getting them in and out.
b) *Likenesses:* (*1*) Control of temperature necessary. (2) Protection from moisture. (3) Some ventilation required.

Looking Back to Unit 11 (p. 545). 1. The nature of a satisfactory answer should be clear from text material. See also lists of main ideas, given for each problem pages 251, 254, 257, and 260.

2. *Saturated soil* is filled with water between its particles.

Dry farming is a plan followed by farmers to save all the rainfall. To do this, they keep the upper layer of soil well broken up and loose in order to prevent the rise and loss of soil water. During some years they also let each field remain idle, although cultivated, in order to store up water for future crops.

Crop rotation is the growing of a series of different crops one after the other. Usually one is a legume to add nitrogen to the soil.

Tuberculin test is used on cattle to tell whether they have tuberculosis.

Capillary action is the process by which water moves through small spaces in materials such as wicks, tubes, and soil.

Fertility is the ability of soil to produce good crops because it can supply the proper amounts of the chemicals needed by plants for growth.

A *veterinarian* is an animal doctor.

Roughage applies to foods that are coarse and bulky. It is needed by animals to help make the intestines work well.

Soil analysis is made to tell a farmer what elements are lacking in the soil. When he knows this, he can add the proper kind of fertilizer, plant the right crops, etc.

A *commercial fertilizer* is a material, such as raw rock phosphate, ground bone, nitrate of soda, etc., that is added to soil to supply the elements that it lacks.

Predaceous insects are insects that prey upon other insects.

Additional Exercises (p. 545). 1. (*a*) To keep soil fertile; (*b*) to help in fight against weeds; (*c*) to help in fight against insects; (*d*) to help in fight against plant diseases.

2. (*a*) To let water and air into soil; (*b*) to help keep down weeds; (*c*) to help kill insects in soil; (*d*) to prevent rise and loss of soil water.

PAMPHLETS AND BULLETINS FOR UNIT 11

Agricultural Leaflets: No. 2. *Cutworms in the Garden.* 5c
  No. 163. *Legumes in Soil Conservation Practices.* 5c
Agriculture Misc. Publication 318. *4-H Club Insect Manual.* 15c
Farmers' Bulletins: No. 218. *School Garden.* 5c
  No. 1743. *Hotbeds and Coldframes.* 5c
  No. 1784. *Nitrogen-fixing Bacteria and Legumes.* 5c

VISUAL MATERIAL

Motion Pictures

Encyclopaedia Britannica Films
  "Corn"; "Cotton Growing"; "Irrigation"; "Market Gardening"; "The Orange Grower"
Society for Visual Education. "Dairy Management"
United States Department of Agriculture. Extension Service, Office of Motion Pictures. Subjects on agriculture, stock, etc. Obtain through local county agricultural agent. Pay transportation.

Photographs

J. I. Case Threshing Machine Co., Racine, Wis.
  Harvesting Scenes (free)
The McCormick Sales Co., Baltimore, Md.
  Common Insect Enemies of Man (free)

Charts

Conference for the Prevention of Grain Rust, 300 Lewis Bldg., Minneapolis, Minn. Colored illustrations of development of black stem rust. Wall chart (free)
United States Department of Agriculture
  Bureau of Entomology. Chart showing control of corn borer.
  Plant Disease Posters. 7 × 12. 5c
United States Office of Education. (Educational illustration.) Potato spraying and harvesting. 15 × 12 in. 5c

PART THREE

Apparatus and Materials for Experimental Work

The following lists have been prepared to assist teachers in checking their equipment: (1) general lists of laboratory apparatus and materials, tools, and chemicals; (2) lists of laboratory apparatus and materials, chemicals, other apparatus and materials from local stores or home, and living materials needed especially for *Book 2*. They include only the standard apparatus that should be available in science classrooms for the best economy of pupil and teacher time. Much of it can be improvised, or inexpensive substitutes may be arranged where necessary.

Quantities listed provide only for having the experiments done as demonstrations or by one group of students at a time, or are practical minimum amounts for purchase. If a different plan is used, appropriate increases in the quantities should be made. Approximate costs, based on prices listed in catalogs of supply companies are given in each list except for those items which may well be obtained free.

The general list includes items which are needed in any science room; practically every item would ordinarily be used in the study of each of the three books. A few of the articles listed are not actually called for in experiments but are almost indispensable. Many will be useful for pupils doing the "Problems to Solve."

There are also practical suggestions for ordering and caring for apparatus and materials and the addresses of some leading scientific supply companies.

1. GENERAL LISTS OF APPARATUS AND MATERIALS

LABORATORY APPARATUS AND MATERIALS

QUANTITY	ITEM	APPROXIMATE COST
1	aquarium, 6-gal.	$6.00
1	aquarium dip net	.20
1	balance, spring, graduated in ounces and grams	.65
6	beakers, Pyrex, 250 or 350 cc.	1.20
6	bottles, wide-mouth, 8 oz.	.43
1	burner, Bunsen (if gas is available; otherwise some satisfactory source of heat)	.50
12	candles, paraffin	.25
2	clamps, burette, single, adjustable	.60
2	clamps, right-angle	.50
1 bag	corks, assorted, some ordinary shapes, some flat	.55
1	cylinder, graduated, glass, 100 cc.	.85
4	dry cells	1.20
2	evaporating dishes, porcelain, 3 in. (75 mm.) dia. or larger	.36
1 box	filter paper (100 circles), 12 cm. dia.	.16
2	flasks, Pyrex, Erlenmeyer, 300 cc. or larger	.44
6	flower pots, medium size	.50
1	funnel, glass, 3 in. (75 mm.) dia.	.28
2	glass plates, 12 x 12 in. (to cover jars and pans)	.80
3	glass plates, 3 x 3 in.	.12
1 lb.	glass tubing, 3-4 mm. outside dia.	.60
1 lb.	glass tubing, 6 mm. outside dia.	.90
18 in.	glass tubing, 18 mm. outside dia.	.12
1	jar, glass, 1 qt.	.45
1	jar, glass, 2 qt.	.65
1	lamp chimney, ordinary	.25
1	lodestone	.25
2	magnets, bar (may well be rod-shaped cobalt-chrome)	.80
1	magnet, horseshoe, large (or U-magnet)	.18

QUANTITY	ITEM	APPROXIMATE COST
1	magnifier, tripod	$ 0.75
1	medicine dropper	.05
1	microscope, compound	65.80
½ oz.	microscope cover glasses	.33
½ gross	microscope slides, glass	.60
1 doz.	needles, steel knitting	.30
2	pans, round, flat, enamel, 2 qt. or larger	.60
1	pump, bicycle, hand pressure	.50
1	reading-glass, or other large convex lens	1.00
2	ringstands, with small, medium, and large rings	2.10
6	rubber stoppers, No. 2, 1-hole	.12
6	rubber stoppers, No. 6, 1-hole	.30
6	rubber stoppers, 1-hole, to fit wide-mouth bottles	.36
6	rubber stoppers, 2-hole, to fit wide-mouth bottles	.36
6 ft.	rubber tubing, 5/16 in. inside dia. (for connecting burner)	.72
6 ft.	rubber tubing, 3/16 in. inside dia.	.48
10 lb.	sand, for aquarium	.50
2	stirring rods, glass, 8 in. x 3/16 in. dia.	.20
24	test-tubes, ordinary glass, 6 x ¾ in.	.60
2	test-tubes, Pyrex, 6 x ¾ in.	.10
1	test-tube brush	.10
3	test-tube holders	.30
1	test-tube rack	.40
2	thermometers, chemical 10-110° C. (double-scale graduated also on Fahrenheit)	2.40
1	trip scales, with 1 set brass weights—1-500 gm.	10.80
6	tumblers, glass	.60
¼ lb.	wire, iron, bare, No. 22 or 24	.13
1 spool	wire, iron, No. 30	.30
2 lb.	wire, copper, double cotton-covered, No. 18 or 22	1.80
2	wire gauze, iron, 6 x 6 in.	.20
		$112.69

TOOLS

QUANTITY	ITEM	APPROXIMATE COST
1 set	auger bits, 1 each, ¼, ½, 1 in.	$1.60
1	brace	1.50
1	file, round, small (4-in.)	.15
1	file, triangular, 4-in. or 6-in.	.12
1	forceps, steel or brass	.15
1	hammer, claw type	.25
1	knife, paring or large pocket-size	.35
2	needles, dissecting	.10
1	pliers, 6-in., wire cutting	.30
1	scalpel	.35
1	scissors, small, slender	.45
1	screw-driver, 4-in. blade	.25
1	shears, strong	1.00
1	trowel or spade	.30
		$6.87

CHEMICALS

QUANTITY	ITEM	APPROXIMATE COST
1 lb.	acid, hydrochloric, concentrated	$0.52
1 lb.	acid, nitric, concentrated	.54
1 lb.	acid, sulphuric, concentrated	.52
1 pt.	alcohol, denatured	.30
1 lb.	ammonium hydroxide, technical	.51
1 lb.	calcium oxide (for making limewater)	.30
1 lb.	copper (cupric) sulphate, technical	.30
1 cube	gum camphor	.30
4 oz.	iodine, Lugol's solution (to be diluted)	.40
1 lb.	potassium nitrate	.30
1 lb.	sodium bicarbonate (baking soda)	.20
1 lb.	sodium chloride (table salt)	.20
1 lb.	starch, laundry	.20
		$4.59

2. LISTS OF APPARATUS AND MATERIALS NEEDED ESPECIALLY FOR BOOK 2

Laboratory Apparatus and Materials

QUANTITY	ITEM	APPROXIMATE COST
1 set	capillary tubes (7 different diameters)	$ 0.90
1	flask, Erlenmeyer, pyrex, 500 cc.	.25
1	jar, battery (6 in. dia. x 8 in. high)	.80
1 pr.	Magdeburg hemispheres (optional)	6.00
1	motor, small electric	2.00
6	Petri dishes, pyrex, 100 mm. dia. x 15	2.28
1	vacuum pump (optional)	4.50
1	watch glass, 3 in. dia. (package of 10)	.50
		$17.23

Chemicals

QUANTITY	ITEM	APPROXIMATE COST
	alcohol, ethyl (80% or more)	
¼ lb.	agar, shredded	.55
1 lb.	alum (aluminum potassium sulphate)	.21
2 oz.	beef extract	.55
1 oz.	chloretone, crystalline (optional)	1.00
1 lb.	ether	.74
1 lb.	gelatine, unflavored granulated	.90
1 lb.	limewater	.30
1 oz.	mercuric chloride	.20
1 sheet	touch paper (or 1-oz. bottle smoke screen chemical at $0.50)	.10
		$ 4.55

Other Apparatus and Materials from Local Stores or Home

QUANTITY	ITEM
1	ball, rubber (size of tennis ball)
1	ball, tennis
1	blotting paper, large piece
1	block soft wood
1	bottle, milk (qt. or pt.)
1	box, small cube-shaped (same diameter as rubber ball)
2	boxes, shallow cardboard
1	can or bucket, 1 ft. deep
11	cans, pint
1	can, quart
1	can, varnish, 1 gal. with air-tight stopper
1 piece	cardboard, 2 ft. sq.
1 piece	cheesecloth, 8x8 in.
	cloth for germinating seeds
1 piece	cloth, thin 2x2 in.
	cloth (p. 174)
1	coin
1 lb.	cotton, absorbent
1	cup, tin
1	filter, cloth or cotton
1 piece	glass, window-pane 3x6 in.
1 piece	glass, window-pane 6x6 in.
	incense

QUANTITY	ITEM
1	incubator, small electric
1 bottle	ink
3	jars, glass
1 pkg.	labels, gummed
1	lamp wick
	limestone, sample of
	matches
3	match sticks
1 piece	metal (large piece)
1	nail, large
1	nail, medium-sized
1	needle, new
2	plates, dinner
1	pan, large, with cover
1 piece	paper, 30 in. sq.
1	radiator, electric
3 pkg.	razor blades, single edge
2	saucers
	sand, for cuttings
5 lb.	sand, dry
	sandstone, sample of
1	screen, paper
	shale, sample of
several	stones, weathered
1 piece	string, 18 in.
1	toaster, electric
1 pkg.	toothpicks
	towel paper
1	tin-can lid
1 piece	tin-foil, 3x3 in.
1	tray (or board)
1	vacuum cleaner
1	vaseline

Materials to Be Obtained When Needed

(Because of the perishable nature of many of these items, they should be obtained a short time before they are needed. Page references to the text are given to indicate exactly when they will be required.)

QUANTITY	ITEM
	bean seeds (p. 466)
several pieces	beef, boiled lean (p. 361)
several	begonia leaves (p. 447)
several	branches, tree—½ in. dia.; 1 in. dia.; 6 in. dia., or tree stump (p. 470)
slices	bread (p. 444)
several	Bryophyllum leaves (p. 447)
several	bulbs, paper white narcissus (p. 447)
	corn seeds (pp. 455, 466, 496)
1 doz. or more	eggs, hens', fertile (p. 475)
	eggs, frog or salamander (p. 482)
	flowers, perfect—lilies or primroses (p. 452)
1	geranium plant
1	goldfish, small (optional, pp. 374-377)
1	heart, sheep or beef, (optional, pp. 374-377)
1	hen (p. 475)
	ice (pp. 139, 273, 276)
1	joint (sheepshank or other uncut joint) (p. 357)
1	leg, fowl or meat animal, muscles attached (p. 361)
	lima bean seeds (p. 455)
1	lungs and windpipe of sheep (p. 489)
	milk, unclean (p. 410)
1	nest for hen (p. 475)
	plants for aquarium (p. 482)
	Pleurococcus (p. 443)
1	potato, Irish (p. 447)
1	potato, sweet (p. 447)
several	pussy-willow branches with catkins (p. 447)
several	shoots, unleafed—ash, buckeye, horse chestnut, etc.
	soil (pp. 466, 496)
	soil, sandy, loam, clay (pp. 135, 496)

3. SUGGESTIONS FOR ORDERING AND CARING FOR APPARATUS AND MATERIALS

In equipping the laboratory much depends on local conditions and available funds. No teacher of introductory science should feel it necessary to have a large appropriation for apparatus and materials. He will find available in other science laboratories many materials that he can borrow, and his students will gladly help him bring to the laboratory from home and neighborhood stores a considerable portion of the necessary supplies. It is only essential to plan far enough in advance for the experimental work and then proceed to use to the best advantage such supplies as are available through purchase, through loan by other science teachers, and through the teacher's ingenuity and pupils' assistance.

If the apparatus and materials are properly cared for, and if pupils take pride in helping to provide essential materials, the store of equipment may be built up within a few years. Some materials must be purchased, of course, but there are ways to raise the necessary funds even if the school appropriation is smaller than the amount needed.

ORDERING APPARATUS AND MATERIALS

In ordering supplies it is first necessary to survey the course to be taught and then to select that material which appears to be most fundamental to the proper study of the course. The lists that are given represent these fundamental materials for *Science Problems, Book 2.*

The next step is to submit copies of your list of necessary materials to three or four of the leading laboratory supply companies for an estimate. This step applies, of course, to those articles that cannot be obtained from home or from neighborhood stores. A list of companies is given on page 273. Catalogs (that may be had on request) from two or three of the nearest supply houses may profitably be consulted in making your list.

When the estimates are received, the next step is to place the order in whole or in part with the company (or companies) that furnishes the best estimate on the entire order or on any items of the order. Having the catalogs of the companies at hand, it will be easy to look up the specifications of any item that they quote.

In places where the teacher does not find it possible or practicable to proceed as suggested, the list may be sent to the purchasing agent or principal, who will forward it to the supply companies.

If a card index is kept for all equipment, it will be an easy matter to know at any time what equipment and supplies are on hand and also to make out the order for the next year. Some teachers prefer to keep a notebook list of supplies on hand. Such a list is not as flexible or as handy as an alphabetical card index.

Bar magnets		C.A. Co. Cat. No. 48			Case 8 Shelf C
Date	On Hand	Ordered	No.	Price	Remarks
10/1/41	2	2/1/39	2	.80	Loaned to Mr. Thomas 1/15/40 Returned 2/12/40

FIG. 19. FORM FOR LABORATORY INDEX CARD

The authors have found that a card index of apparatus and materials is a great convenience in ordering and in making the annual inventory. Furthermore, such a card index is a permanent part of the laboratory, and a new teacher may quickly familiarize himself with the apparatus on hand and its location. The form of card found most useful is shown in Figure 19. Pupils will gladly help in ruling the cards; they may be prepared from a stencil, or the school printing class may make them. The 4 x 6 size has been found to be most satisfactory.

Such a card may contain an exact description of the article with a reference to catalog number or letter of a laboratory supply company, as well as the price, as indicated on the form shown (p. 272). With the item once entered on the card, it is not necessary to turn to the catalog every time a new order is to be placed. It is only necessary to leaf through the cards as the inventory is made, enter the number or quantity on hand, and if an additional supply is needed, make proper entry in the columns for that purpose. Any secretary or pupil can then take the cards and make up a list of items to be ordered. If prices are entered on the cards, queries from the principal or superintendent concerning the value of apparatus and materials on hand may be quickly and accurately answered.

Caring for Apparatus and Materials

If enough cabinet space is available, the authors have found the following plans and practices of value:

a) Store all "chemicals" and other materials in alphabetical order.

b) Store assembled apparatus used with particular units in groups by units.

c) Have such commonly used apparatus as test-tubes, Bunsen burners, and matches near or on the demonstration table.

d) If apparatus is out of order, do not put it away until it is repaired.

e) Have pupils acquainted with the plan of storing apparatus so that they will not waste time in getting it and so that it will always be returned to the proper place.

f) Number the sections of cabinets and cases in order.

4. SCIENTIFIC SUPPLY COMPANIES

Biological Supply Co., 1176 Mt. Hope Ave., Rochester, N. Y.
California Biological Service, 1612 W. Glenoaks Blvd., Glendale, Calif. (Soilless plant culture)

Cambosco Scientific Co., 37 Antwerp St., Brighton Station, Boston 35, Mass.
Carolina Biological Supply Co., Elon College, N. C.
Central Scientific Co., 1700 Irving Park Road (Lakeview Station), Chicago 13, Ill.; 441 Clinton Avenue, Newark 8, N. J.; 79 Amherst St., Cambridge 42, Boston, Mass.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago 22, Ill.
Clay-Adams Co., 44 E. 23rd St., New York 10, N. Y. (Models and charts)
Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago 40, Ill. (Models and charts)
Empire Laboratory Supply Co., 507-559 W. 132d St., New York, N. Y.
General Biological Supply House, 761-763 E. 69th Place, Chicago 37, Ill.
Heil Corp., 210 S. Fourth St., St. Louis 2, Mo.
Marine Biological Laboratory, Woods Hole, Mass.
Michigan Biological Supply House, 206 S. First St., Ann Arbor, Mich.
Millard Heath Co., 325 Olive St., St. Louis, Mo.
New York Scientific Supply Co., 28 West 30th St., New York 1, N. Y.
A. J. Nystrom and Co., 3333 Elston Ave., Chicago 18, Ill. (Charts)
Oregon Biological Supply Co., 303 N.E. Multnomah, Portland 12, Ore.
Scientific Supplies Co., 122 Jackson Ave., Seattle 4, Wash.
Standard Scientific Supply Corp., 34-38 W. 4th St., New York 12, N. Y.
Wards Natural Science Establishment, 3000 Ridge Road, East, Rochester 9, N. Y.
W. M. Welch Scientific Co., 1515 N. Sedgwick St., Chicago 10, Ill.
Western Laboratories, 826 Q St., Lincoln, Nebr.

PART FOUR

Publications and Teaching Materials for the Science Teacher

1. READING AND REFERENCES

GENERAL READING ON THE TEACHING OF SCIENCE

Croxton, W. C. *Science in the Elementary School.* New York: McGraw-Hill, 1937.

Curtis, F. D. *A Digest of Investigations in the Teaching of Science.* Philadelphia: Blakiston, 1925.

Curtis, F. D. *A Second Digest of Investigations in the Teaching of Science.* Philadelphia: Blakiston, 1931.

Curtis, F. D. *A Third Digest of Investigations in the Teaching of Science.* Philadelphia: Blakiston, 1939.

Downing, E. R. *An Introduction to the Teaching of Science.* Chicago: University of Chicago Press, 1934.

Heiss, E. D., Obourn, E. S., and Hoffman, C. W. *Modern Methods and Materials for Teaching Science.* New York: Macmillan, 1940.

Hunter, George W. *Science Teaching at Junior and Senior High School Levels.* New York: American Book, 1934.

Mayfield, John C., Parker, Bertha M., Blough, Glenn O. *Science Instruction in Elementary and High School Grades.* Chicago: University of Chicago Laboratory Schools, 1939.

Miller, David F., and Blaydes, Glenn W. *Methods and Materials for Teaching Biological Sciences.* New York: McGraw-Hill, 1938.

National Society for the Study of Education, Thirty-first Yearbook, Part I. *A Program for Teaching Science.* Forty-sixth Yearbook, Part I. *Science Education in American Schools.* Chicago: University of Chicago Press, 1932 and 1947.

Noll, Victor H. *The Teaching of Science in Elementary and Secondary Schools.* New York: Longmans, 1939.

Palmer, E. Laurence. *Nature Magazine's Guide to Science Teaching.* Washington, D. C.: American Nature Association, 1936.

Preston, Carleton E. *The High School Science Teacher and His Work.* New York: McGraw-Hill, 1936.

Progressive Education Association. *Science in General Education.* New York: Appleton-Century, 1938.

Science Instruction and America's Problems. Washington, D. C.: Department of Science Instruction of the N. E. A., 1940.

Skinner, Charles E. (ed.) *Educational Psychology*. New York: Prentice-Hall, 1936.

Slavson, S. R., and Speer, R. K. *Science in the New Education*. New York: Prentice-Hall, 1934.

Underhill, O. E. *The Origins and Development of Elementary-School Science*. Chicago: Scott, 1941.

Reading on Various Aspects of Science Teaching

The American Institute of the City of New York, 310 Fifth Ave., New York, N. Y., is organized to direct and utilize the imaginative faculties of youth. It has 730 juvenile clubs under its wings. Write to it for information about science clubs.

Atyeo, Henry C. *The Excursion as a Teaching Technique*. New York: Bureau of Publications, Teachers College, Columbia University, 1939.

Cook, Dorothy E., and Rahbek-Smith, Eva. *Educational Film Catalog*. New York: Wilson, H. W., 1939.

Exelby, C. L., and Gambill, L. B. *Science Club Manual*. Lansing, Mich.: The National Club Manual Co., 1931.

Harrison, Margaret. *Radio in the Classroom*. New York: Prentice-Hall, 1937.

Hoban, Charles F., Hoban, Charles F., Jr., and Zisman, Samuel B. *Visualizing the Curriculum*. New York: Cordon, 1937.

Hurley, Richard James. *Key to the Out-of-Doors*. New York: Wilson, H. W., 1938. (Lists books, films, slides, etc.)

Laine, Elizabeth. *Motion Pictures and Radio: Modern Technique for Education*. New York: McGraw-Hill, 1938.

Moore, E. M., *Youth in Museums*. Philadelphia: University of Pennsylvania Press, 1941.

Ramsey, Grace F. *Educational Work in Museums of the United States*. New York: Wilson, H. W., 1938.

Ruch, G. M. *The Objective or New-Type Examination*. Chicago: Scott, 1929.

Towne, Mary E. *Teaching with Motion Pictures: A Guide to Sources of Information and Materials*. Teachers College Library Contributions, No. 1. New York: Teachers College, Columbia University, 1940.

Turtox Service Leaflets, Turtox Teacher's Manual. Chicago: General Biological Supply House. Free.

Vinal, W. G. *Nature Recreation*; group guidance for the out-of-doors. New York: McGraw-Hill, 1940.

Wood, B., and Freeman, F. N. *Motion Pictures in the Classroom*. Boston: Houghton, 1929.

Woodring, M. N., Oakes, M. E., and Brown, H. E. *Enriched Teaching of Science in the High School.* New York: Bureau of Publications, Teachers College, Columbia University, Revised Ed. 1941. (Lists available free materials.)

REFERENCE BOOKS

Many of these books are surveys of important departments of science or of the whole science field. Non-technical in style, they are designed to broaden the reader's background of information and increase his insight into the significance of science.

Allee, Warder C. *The Social Life of Animals.* New York: Norton, 1938.

Bartky, Walter. *Highlights of Astronomy.* Chicago: University of Chicago Press, 1936.

Bond, Phyllis. *Watching Wild Life.* New York: Longmans, 1937.

Borsook, Henry. *Vitamins: What They Are and How They Can Benefit You.* New York: Viking, 1940.

Buchsbaum, Ralph. *Animals without Backbones.* Chicago: University of Chicago Press, 1948.

Carlson, Anton J., and Johnson, Victor. *The Machinery of the Body.* Chicago: University of Chicago Press, 1941.

Chamberlain, Charles J. *Elements of Plant Science.* New York: McGraw-Hill, 1930.

Clendenning, Logan. *The Human Body.* (Rev. Ed.) New York: Knopf, 1945.

Collingwood, G. H. *Knowing Your Trees.* Washington, D. C.: American Forestry Association, 1947.

Coulter, Merle C. *The Story of the Plant Kingdom.* Chicago: University of Chicago Press, 1936.

Cressy, Edward. *Discoveries and Inventions of the Twentieth Century.* New York: Dutton, 1930.

Croneis, Carey, and Krumbein, William C. *Down to Earth.* Chicago: University of Chicago Press, 1936.

Curie, Eve. *Madame Curie: A Biography.* New York: Doubleday, 1937.

Fairchild, David G. *The World Was My Garden.* New York: Scribner, 1938.

Findlay, Alexander. *A Hundred Years of Chemistry.* New York: Macmillan, 1937.

Furnas, C. C. *The Next Hundred Years.* New York: Blue Ribbon, 1938.

Harvey, William. *Simple Lessons in Human Anatomy.* Chicago: American Medical Association, 1931.

Hylander, C. J. *Plants and Man.* Philadelphia: Blakiston, 1941.

Jacobs, Morris J. *The Chemical Analysis of Foods and Food Products.* New York: Van Nostrand, 1938.

The Layman Scientist in Philadelphia. Edited by W. Stephen Thomas. Committee on Education and Participation in Science. Philadelphia, Pa.: American Philosophical Society.

Lemon, Harvey B. *From Galileo to the Nuclear Age.* Chicago: University of Chicago Press, 1946.

Lynde, C. J. *Science Experiments with Home Equipment.* Scranton, Pa.: Int. Textbook, 1937.

Lynde, C. J. *Science Experiments with Inexpensive Equipment.* Scranton, Pa.: Int. Textbook, 1939.

Matlin, D. A. *Growing Plants Without Soil.* New York: Chemical Pub., 1940.

Orientation in Science. By eleven members of the University of Rochester faculty. Edited by C. W. Watkeys. New York: McGraw-Hill, 1938.

Outline of Science, The. Edited by J. Arthur Thomson. New York: Putnam, 1937.

Pfeiffer, John. *Science in Your Life.* New York: Macmillan, 1939.

Richards, Harold. *The Universe Surveyed.* New York: Van Nostrand, 1937.

Robbins, William J., and Rickett, Harold W. *Botany.* New York: Van Nostrand, 1934.

Snell, Foster Dee and Cornelia T. *Chemicals of Commerce.* New York: Van Nostrand, 1939.

Vallery-Radot, René. *Life of Pasteur.* New York: Garden City Pub. Co., 1940.

Wells, H. G., and Huxley, Julian S. *The Science of Life.* New York: Doubleday, 1934.

World and Man As Science Sees Them. By twelve members of University of Chicago faculty. Edited by Forest Ray Moulton. Chicago: University of Chicago Press, 1937.

Publishers' Names and Addresses

This list includes the names and addresses of the publishers of the books listed in *Readings in Science* in the text, as well as of those given in the *Guidebook.* The publishing companies are listed alphabetically according to the abbreviations commonly used for them.

American Book: American Book Company, 88 Lexington Ave., New York 16, N. Y.

American Forestry Association, 919 Seventeenth St., N.W., Washington 6, D. C.

Amer. Med. Assoc.: American Medical Association, 535 N. Dearborn St., Chicago 10, Ill.

American Nature Association, 1214 Sixteenth St., N.W., Washington 6, D. C.

American Philosophical Society, Independence Square, Philadelphia 6, Pa.

American Viewpoint Society, Inc., 13 Astor Place, New York, N. Y.

Appleton-Century: Appleton-Century Crofts, 35 W. 32nd St., New York 1, N. Y.

Beacon Press: The Beacon Press, Inc., 25 Beacon St., Boston, Mass.

Bell and Sons: George Bell and Sons, Ltd., York House, 6 Portugal St., Lincoln's Inn Fields, London, WC2.

Blakiston: P. Blakiston's Sons and Co. (Now the Blakiston Company), 1012 Walnut St., Philadelphia 5, Pa.

Blue Ribbon: Blue Ribbon Books, 14 W. 49th St., New York, N. Y.

Bobbs: Bobbs-Merrill Company, 724 N. Meridian St., Indianapolis 7, Ind.

Boy Scouts of America, 2 Park Ave., New York 16, N. Y.

Chemical Pub.: Chemical Publishing Co., Inc., 26 Court St., Brooklyn 2, N. Y.

Christopher: Christopher Publishing House, 1140 Columbus Ave., Boston 20, Mass.

Columbia Univ. Press: Columbia University Press, 2960 Broadway, New York 27, N. Y.

Compton: F. E. Compton and Co., 1000 N. Dearborn St., Chicago, Ill.

Cordon: The Cordon Co., Inc., New York, N. Y. (Its publications have been acquired by The Dryden Press, 386 Fourth Ave., New York 16, N. Y.)

Coward-McCann: Coward-McCann, Inc., 2 W. 45th St., New York 19, N. Y.

Crowell: The Thomas Y. Crowell Company, 432 Fourth Ave., New York 16, N. Y.

Day: John Day Co., Inc., 2 W. 45th St., New York, N. Y.

Dodd: Dodd, Mead and Company, Inc., 432 Fourth Ave., New York 16, N. Y.

Doubleday: Doubleday, Doran and Co., Inc., 14 W. 49th St., New York 20, N. Y.

Duffield: Duffield, Green, Inc. (Acquired by Dodd, Mead and Company)
Dutton: E. P. Dutton and Co., Inc., 300 Fourth Ave., New York 10, N. Y.
Flanagan: A. Flanagan Company, 920 N. Franklin St., Chicago, Ill.
Follett: Follett Publishing Co., 1255 S. Wabash Ave., Chicago, Ill.
Funk: Funk and Wagnalls Company, 153 East 24th Street, New York, N. Y.
Garden City Publishing Co., Inc., 14 W. 49th St., New York, N. Y.
Gardner: Wells, Gardner, Darton and Co., Ltd., 65-71 Brighton Road, Redhill, Surrey.
Ginn: Ginn and Co., Statler Building, Boston 17, Mass.
Girl Scouts of America: Girl Scouts, Inc., 155 East 44th Street, New York 17, N. Y.
Greenberg: Greenberg, Publisher, Inc., 201 E. 57th St., New York 22, N. Y.
Grolier Soc.: Grolier Society, 2 W. 45th St., New York, N. Y.
Hale: Ralph T. Hale and Company, 6 Beacon Street, Boston 8, Mass.
Hale, E. M.: E. M. Hale and Company Publishers, 320 S. Barstow St., Eau Claire, Wis.
Harcourt: Harcourt, Brace and Company, Inc., 383 Madison Ave., New York 17, N. Y.
Harper: Harper and Brothers, 49 E. 33rd St., New York 16, N. Y.
Harter: Harter Publishing Company. (Acquired by Beckley-Cardy Co., 1632 Indiana Ave., Chicago, Ill.)
Heath: D. C. Heath and Company, 285 Columbus Ave., Boston 16, Mass.
Holt: Henry Holt and Company, Inc., 257 Fourth Ave., New York 10, N. Y.
Houghton: Houghton, Mifflin and Co., 2 Park St., Boston, Mass.
Int. Textbook: International Textbook Company, 1001 Wyoming Ave., Scranton, Pa.
Knopf: Alfred A. Knopf Inc., 501 Madison Ave., New York, N. Y.
Lippincott: J. B. Lippincott Company, East Washington Square, Philadelphia, Pa.
Little: Little, Brown and Company, 34 Beacon St., Boston, Mass. (School books acquired by D. C. Heath)
Longmans: Longmans, Green and Co., 55 Fifth Ave., New York 3, N. Y.
Lothrop: Lothrop, Lee, and Shepard Co., 419 Fourth Ave., New York 16, N. Y.
Macmillan: The Macmillan Co., 60 Fifth Ave., New York, N. Y.

McGraw-Hill: McGraw-Hill Book Company, Inc., 330 W. 42d St., New York 18, N. Y.

Macrae-Smith: Macrae-Smith Co., 225 South 15th St., Philadelphia 2, Pa.

Messner: Julian Messner, Inc., Publishers, 8 W. 40th St., New York 18, N. Y.

Morrow: William Morrow and Co., Inc., 425 Fourth Ave., New York 16, N. Y.

N. E. A.: National Education Association of the United States, 1201 Sixteenth St., N.W., Washington 6, D. C.

Newman, Hugh F.: Hugh F. Newman and Company, 420 E. Seventh St., Los Angeles, Calif.

Norton: W. W. Norton and Co., Inc., 101 Fifth Ave., New York, N. Y.

Owen: F. A. Owen Publishing Company, Dansville, N. Y.

Oxford: Oxford University Press, 114 Fifth Ave., New York, N. Y.

Prentice-Hall: Prentice-Hall, Inc., 70 Fifth Ave., New York, N. Y.

Public School: Public School Publishing Co., 509-513 N. East St., Bloomington, Ill.

Putnam: G. P. Putnam's Sons, 2-6 W. 45th St., New York, N. Y.

Quarrie: W. F. Quarrie and Co. (now The Quarrie Corporation) 35 E. Wacker Drive, Chicago, Ill.

Rand: Rand McNally and Company, 536 S. Clark St., Chicago, Ill.

Reinhold: Reinhold Publishing Corporation, 330 W. 42d St., New York 18, N. Y.

Reynal: Reynal and Hitchcock, Inc., 8 West 40th St., New York, N. Y.

Scott: Scott, Foresman and Company, 433 East Erie Street, Chicago 11, Ill.

Scribner: Charles Scribner's Sons, 597-599 Fifth Ave., New York 17, N. Y.

Silver: Silver, Burdett and Company, 45 E. Seventeenth St., New York 3, N. Y.

Stokes: Frederick A. Stokes Company. (Acquired by J. B. Lippincott Company)

Univ. of Chicago Press: University of Chicago Press, 5750 Ellis Ave., Chicago 37, Ill.

Univ. of Pa. Press: University of Pennsylvania Press, 3436 Walnut St., Philadelphia, Pa.

University Society Inc., 468 Fourth Ave., New York 16, N. Y.

Van Nostrand: D. Van Nostrand Company, Inc., 250 Fourth Ave., New York 10, N. Y.

Viking: Viking Press: 18 E. 48th St., New York 17, N. Y.

Wiley: John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y.

Williams and Wilkins: The Williams and Wilkins Company, Mt. Royal and Guilford Aves., Baltimore 2, Md.

Wilson, H. W.: H. W. Wilson Co., 950 University Ave., New York 52, N. Y.

Winston: John C. Winston Company, 1006-1026 Arch St., Philadelphia 7, Pa.

World Book: World Book Company, 313 Park Hill Ave., Yonkers-on-Hudson, N. Y.

2. PERIODICALS FOR TEACHERS AND PUPILS

(Starred [*] publications are suitable for pupils.)

The American Biology Teacher, published by The National Association of Biology Teachers, N. Queen St. and McGovern Ave., Lancaster, Pa. (Monthly from October to May. Annual membership in The National Association of Biology Teachers, including subscription, $2.00.)

**American Forests*, published by The American Forestry Association, 919 Seventeenth St., Washington 6, D. C. (Monthly. $5.00 a year; 50c a copy.)

*Audubon Magazine, formerly *Bird Lore*, published by The National Audubon Society, 1000 Fifth Avenue, New York 28, N. Y. (A bimonthly magazine devoted to the study and protection of birds and mammals. $2.50 a year; 45c a copy.)

**Building America*, published for The Society for Curriculum Study, 140 N. 6th St., Philadelphia, Pa. Distributed by the Americana Corporation, 2 W. 45th St., New York, N. Y. (Monthly from October through May. $3.00 for single set of 8 units; 45c a single copy.)

Consumers' Guide, published by the Department of Agriculture, Washington, D. C. (Monthly from June through September; semi-monthly from October through May. 50c a year; 5c a copy.)

**Current Science*, published by American Education Press, Inc., 400 Front St., Columbus, Ohio. (Weekly during school; $1.20 a year.)

**Frontiers*, A Magazine of Natural History, published by The Academy of Natural Sciences of Philadelphia, 19th St. and The Parkway, Philadelphia 3, Pa. (Five times a year—October, December, February, April, June. $1.50 a year.)

Hygeia, The Health Magazine, published by The American Medical Association, 535 N. Dearborn St., Chicago 10, Ill. (Monthly. $2.50 a year; 25c a copy.)

Journal of Chemical Education, official publication of The Division of Chemical Education of the American Chemical Society, 20th and Northampton Sts., Easton, Pa. (Monthly. $3.00 a year; 50c a copy.)

**The Junior Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Monthly. $1.50 a year.)

**The National Geographic Magazine*, published by The National Geographic Society, 16th and M Sts., N. W., Washington, D. C. (Monthly. Annual membership in The National Geographic Society, including subscription, $5.00.)

**Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York 24, N. Y. (Monthly except July and August. $5.00 a year; 50c a copy.)

**Nature Magazine*, published by the American Nature Association, 1214 Sixteenth St., N. W., Washington 6, D. C. (Monthly. $4.00 a year; 50c a copy.)

Peabody Journal of Education, published by George Peabody College for Teachers, Nashville, Tenn. The July issue of each year contains Mr. H. A. Webb's "High School Science Library" for the preceding twelve months which may be obtained as a reprint from the author. (Monthly. $2.00 a year; 40c a copy.)

**Popular Mechanics*, 200 E. Ontario St., Chicago 11, Ill. (Monthly. $2.50 a year, $4.00 for two years; 25c a copy.)

**Popular Science Monthly*, published by Popular Science Publishing Co., Inc., 353 Fourth Ave., New York 10, N. Y. (Monthly. $2.50 a year; 25c a copy.)

School Science and Mathematics, publication of the Central Association of Science and Mathematics Teachers, Inc. Published at 450 Ahnaip St., Menasha, Wis. (Monthly except July, August, and September. $3.50 a year; 40c a copy.)

**Science Digest*, published by Science Digest, Inc., 200 E. Ontario St., Chicago 11, Ill. (Monthly, $3.00 a year; 25c a copy.)

Science Education, the official organ of the National Association for Research in Science Teaching, the National Council on Elementary Science, and the Science Association of the Middle States. Published by Science Education, Inc., 374 Broadway, Albany, N. Y. (Seven times a year. $2.50 a year; 75c a copy.)

Science News Letter, The Weekly Summary of Current Science, published by Science Service, Inc., 1719 N Street, Northwest, Washington 6, D. C. (Weekly. $5.50 a year, $10.00 for two years; 15c a copy.)

Scientific American, published by Scientific American, Inc., 24 W. Fortieth St., New York, N. Y. (Monthly, $5.00 a year; 50c a copy.)

The Science Teacher, official journal of the National Science Teachers Association. Published at 201 North School Street, Normal, Ill. (Four times a year, $1.25 a year.)

The Scientific Monthly, publication of The American Association for the Advancement of Science, Washington, D. C. Published by The Science Press, Lancaster, Pa. (Monthly. $7.50 a year; 75c a copy.)

3. OTHER MATERIALS FOR TEACHING SCIENCE

SOURCES OF INFORMATION

This section gives a list of organizations and agencies from which teachers can secure reliable information on various science problems, either free or at a nominal cost. These organizations include commercial companies, scientific societies, museums, and state and United States Government departments and bureaus. Much information on specific problems can be secured also from the community in which one lives.

COMMERCIAL ORGANIZATIONS

Bausch and Lomb, Rochester, N. Y.
Eastman Kodak Company, Rochester, N. Y.
General Electric Company, Schenectady, N. Y.
General Motors Corporation, Research Division, Detroit, Mich.
Metropolitan Life Insurance Company, New York, N. Y.
Taylor Instrument Company, Rochester, N. Y.

MISCELLANEOUS ORGANIZATIONS

American Association for the Advancement of Science, 1515 Massachusetts Ave., N. W., Washington, D. C.
American Chemical Society, Mills Building, Washington, D. C.
American Forestry Association, 919 Seventeenth St., Washington, D. C.
American Home Economics Association, 620 Mills Building, Washington, D. C.
American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.
American Wild Life Institute, Investment Building, Washington, D. C.

National Academy of Science, Washington, D. C.
National Board of Fire Underwriters, 58 John St., New York, N. Y.
National Parks Association, 1624 H St., N. W., Washington, D. C.
Science Service, 1719 N St., Northwest, Washington, D. C.
Smithsonian Institution, Washington, D. C.

MUSEUMS

American Museum of Natural History, New York, N. Y.
Buffalo Museum of Science, Buffalo, N. Y.
Carnegie Institute Museum, Washington, D. C.
Chicago Natural History Museum, Chicago, Ill.
Chicago Zoölogical Park, Brookfield, Ill.
Museum of Science and Industry, Chicago, Ill.
Museum of Science and Industry, Rockefeller Center, New York, N. Y.
National Academy of Science, Washington, D. C.
National Zoölogical Gardens, Washington, D. C.
New York Botanical Gardens, New York, N. Y.
New York Zoölogical Society, New York, N. Y.

STATE DEPARTMENTS

Agriculture, Fisheries, Forests and Waters, Health, Highways

U. S. GOVERNMENT DEPARTMENTS AND BUREAUS

A list of the publications of these departments and bureaus may be secured from the Superintendent of Documents, Washington, D. C.

Sources of Motion-Picture Films

American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Rents films on hygiene, domestic science, biology, general science, physics, chemistry.)
Association on Films (Y.M.C.A. Motion Picture Bureau), 347 Madison Ave., New York 17, N. Y.
Bausch & Lomb Optical Company, Rochester, N. Y. (Free through local B & L dealers)
Caravel Films, Inc., 245 W. 55th St., New York, N. Y. (Free films on science subjects)
Frank R. Church Films, 829 Harrison Ave., Oakland, Calif. (Sells or rents wild life, industrials, and science subjects. Some are free.)
Commercial Motion Picture Productions, 8634 Sunset Blvd., Hollywood, Calif. (To sell)

Du Pont Company, Motion Pictures Bureau, Wilmington, Del. (Free)

Edited Pictures System, Inc., 330 W. 42d St., New York, N. Y. (Sells or rents scientific films.)

Encyclopaedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Ill. (Sells and rents Silent Teaching Films, Sound Motion Pictures and slide films on many science subjects. Now owns large film libraries formerly belonging to Eastman Kodak Company and to Erpi Classroom Films, Inc. For rentals only, write to 207 South Green Street, Chicago, Ill.)

General Electric Company, Educational Service Division, 1 River Road, Schenectady, N. Y. (Rent or free)

Harvard Film Service, The Biological Laboratories, Cambridge, Mass. (Sell or rent sound and silent science subjects.)

International Education Pictures, Inc., 40 Mt. Vernon St., Boston, Mass. (Sell or rent; some are free.)

Kodascope Library, 33 W. 42nd St., New York. (Sell or rent.)

Pyrene Manufacturing Co., Sales Promotion Department, 560 Belmont Ave., Newark, N. J. (Free)

School Films Service, Inc., 55 W. 42d St., New York, N. Y. (Sell or rent science films.)

Society for Visual Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)

Swift & Co., Public Relations Department, Union Stock Yards, Chicago, Ill. (Free)

U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa. (Free)

U. S. Department of Agriculture, Extension Service, Office of Motion Pictures, Washington, D. C. (Free)

The U. S. Office of Education has compiled lists of available films.

United World Films, Inc., 445 Park Ave., New York 22, N. Y. (Now owns large film library formerly belonging to Bell and Howell)

Wild Flowers Preservation Society, 3740 Oliver St., N. W., Washington, D. C. (Sell or rent)

A mimeographed booklet, distributed by the Photographic Section of the Division of Information, U. S. Department of the Interior, Washington, D. C., lists eighty-nine films with brief annotations. Many of these are of science interest. These may be borrowed.

Many state universities have bureaus of visual instruction that have a large supply of films to be rented. It will be worthwhile for a teacher to request a catalog from the bureau in his state. Many of them rent to neighboring states also.

SOURCES OF SLIDES AND FILMSTRIPS

Bray Studios, Inc., 729 Seventh Ave., New York 19, N. Y.
Chicago Academy of Sciences, Chicago, Ill. (Commercial slides)
General Biological Supply House, 761 E. 69th Place, Chicago, Ill.
General Electric Company, Educational Service Division, Schenectady, N. Y. (Commercial slides)
Keystone View Company, Meadville, Pa.
National Audubon Society, 1000 Fifth Ave., New York 28, N. Y.
National Park Service, Department of Interior, Washington, D. C.
Society for Visual Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)
Spencer Lens Company, Buffalo, N. Y.
State Museums. Many lend slides to teachers within their state.
Stillfilm, Inc., Hollywood, Calif.
United States Department of Agriculture, Washington, D. C.
Visual Education Service, Inc., 7024 Melrose Ave., Los Angeles, Calif.
Visual Text Sales Company, Los Angeles, Calif.

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BASIC STUDIES IN SCIENCE

Date 15.2.1955

TEACHER'S GUIDEBOOK

for SCIENCE PROBLEMS

BOOK 3

by

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Preface

The three books of the *Science Problems* series have been written specifically for science reading and science instruction in the seventh, eighth, and ninth grades of American schools. This *Guidebook* is intended to assist administrators and teachers in making the most effective use of the series, and specifically of *Book 3*, by stating the authors' point of view on: (1) the objectives of science instruction at this level; (2) the principles and plan of organization of the series; (3) suggestions for fitting the course to local conditions; (4) the general technique of effective instruction in science; and (5) the principal types of difficulties that pupils meet in their study of science.

The *Guidebook* furnishes detailed helps for teaching each unit and includes correct responses for the exercises. These helps are planned especially for the busy teacher, to relieve him of some of the mechanical labor incident to teaching any course and to make clear the authors' aims and method. Neither this nor any teacher's manual can be a panacea for all teaching difficulties, nor should such a manual interfere with the initiative and individuality of the teacher.

The inexperienced teacher will find this *Guidebook* particularly helpful. The experienced teacher will find in it many suggestions which have come out of actual classroom situations. These he will modify and supplement from his own experiences. If the suggestions serve to assist in modifying the lives of pupils through the development of their intellectual powers and through the acquisition of worth-while knowledge, thus insuring that the pupils will better adjust themselves to their environment and control it, the time and effort spent in the preparation of this guide will have been justified. The authors will be most grateful for any suggestions which teachers may wish to offer and which may be included when the Guidebook is revised.

WILBUR L. BEAUCHAMP
JOHN C. MAYFIELD
JOE YOUNG WEST

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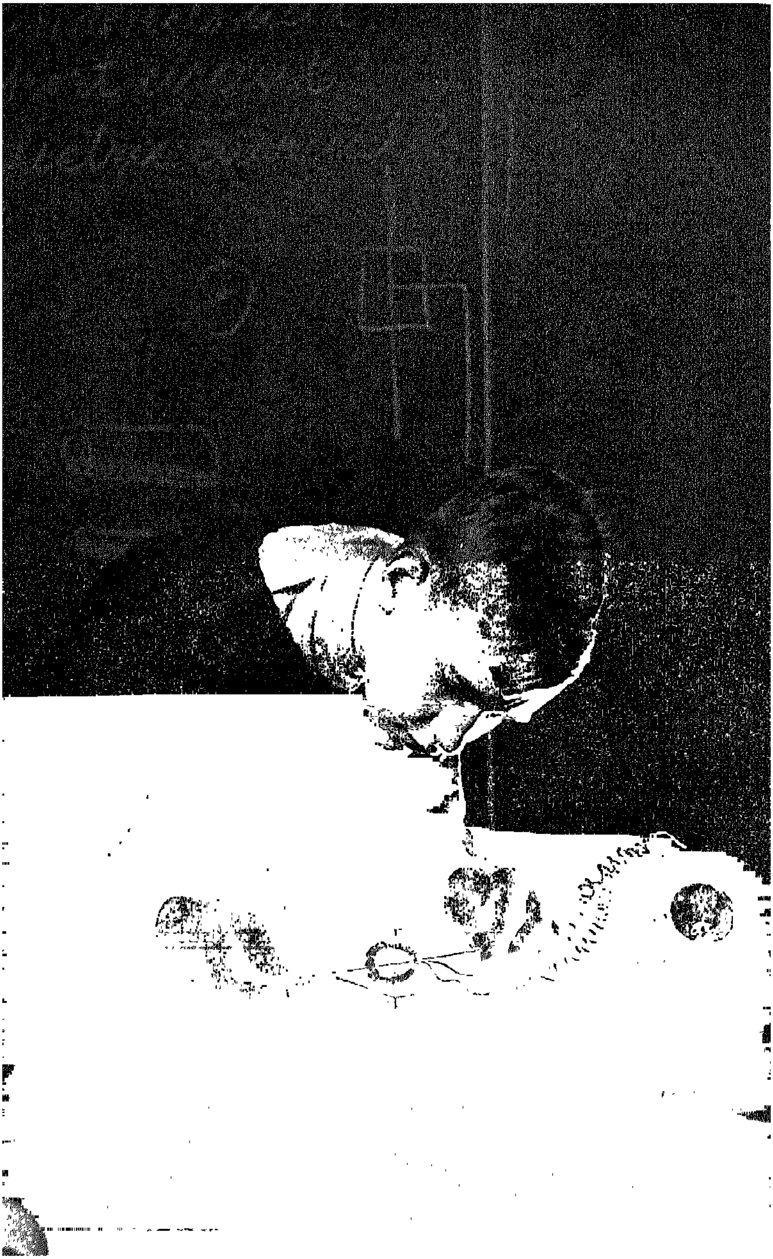

PART ONE

General Considerations

1. INTRODUCTION

The formulation of and instruction in a course in science demand that the teacher have a broad vision and a definite concept of the place and function of science in a liberal education. This is particularly true at the seventh-, eighth-, and ninth-grade levels, for here the objectives, content, and method have not as yet been so clearly determined as they have been in the older, more specialized courses for the later years of the high school.

In planning the science course for the early years of the high school or for the last two years of the eight-year elementary school, the administrator and the teacher who conscientiously strive to provide that science instruction which will best serve to educate the coming citizens of their community must consider carefully the following: (1) the valid objectives of science instruction at this level, (2) a plan of organization of the subject matter for effective teaching, and (3) a technique of classroom procedure which will insure the attainment of the objectives sought. The neglect of any one of these steps makes the teaching of science aimless or even harmful.

In order that administrators and teachers may understand thoroughly the plan of the Science *Problems* series, Part One of the *Guidebook* presents general considerations concerning objectives, selection of subject matter, principles of organization, and technique of instruction. Part Two contains detailed suggestions for the teaching of each unit of *Book 3*. Part Three gives lists of apparatus and materials, suggestions for ordering and caring for apparatus, and also the addresses of laboratory supply companies. Part Four presents certain bibliographical and source materials.

2. OBJECTIVES OF SCIENCE STUDY

The ultimate and practical objective or goal of science study at any level of intellectual attainment is the desirable modification of the responses of the student in life situations. What science subject matter and what methods produce the greatest beneficial result in the life of the pupil is the question which teachers must constantly ask themselves. This concept of education demands that we analyze our science materials and our methods of instruction with the hope of discovering which knowledge, attitudes, habits, appreciations, interests, and ideals are most worth-while. Many analyses of this kind have been made.

At the present time there is no conclusive method of evaluating the objectives of science study. One method which is commonly employed is that of consensus. A few years ago an analysis was made of the objectives found in fifty-one general-science courses published since 1925.* In general, the objectives may be grouped in six classes: Knowledge, Exploration, Abilities, Attitudes, Ideals and Habits, and Interests. The frequency of mention of these various objectives is shown in Table 1, pages 4-5. This frequency of mention is interesting, but is not a valid criterion for determining what the objectives should be. It reveals what others consider to be the objectives.

Another approach to the problem of deciding upon the objectives to be attained has been through appointment of committees by various associations. A committee of the National Society for the Study of Education presented its report in the *Thirty-first Yearbook* of the Society entitled "A Program for Teaching Science." This report was published in 1932. The point of view of this committee is expressed in the following quotations from the report:

> An aim of education that seems consistent with the postulations of modern philosophy is, *Life Enrichment through Participation in*

---

* *Instruction in Science*, Bulletin, 1932, No. 17. Monograph No. 22, United States Department of the Interior, Office of Education.

> a *Democratic Social Order*. . . . The point of view taken here is that life enrichment is in part, and in large part, developed from the understanding of principles and generalizations that ramify into human experience. These principles and generalizations are functional in that they furnish a background for intelligent response to stimuli that recur in common unspecialized experience. The understanding of principles and generalizations comes from the association of ideas that are developed from experiences. These understandings are products of the activities of the school if the ideas from which they are developed are products of classroom activities. It is clear, then, that the school will contribute to life enrichment if its activities are of the kind from which ideas may be developed and if the ideas may in turn be associated with principles and generalizations that are woven into human experience. . . .
>
> A functional understanding of a principle has been attained if the learner has acquired ability to associate with the principle the ideas from his immediate and from his subsequent experiences that are directly related to it and if he is able to apply the principles in practical situations. . . . The objectives may be stated as principles and generalizations that are functional for the individual, in that they enable him to interpret the experiences of living. The objectives may be formulated (1) as statements that function directly in thinking, (2) as statements that describe methods of thinking, and (3) as statements that describe attitudes toward products of thought and toward methods of thinking. These three types of objectives, though distinguishable, cannot be regarded as mutually exclusive. From the point of view of their origins in the educative process, these objectives are closely similar. The findings from science have contributed enormously to thinking, to methods of study, and to the development of scientific attitudes that affect behavior. The principles and generalizations of science must, therefore, occupy considerable place in a program of general education the aim of which is life enrichment. (Pages 42-43)

The *Report of the Committee on the Function of Science in General Education* of the Commission on the Secondary School Curriculum of the Progressive Education Association was published in 1938. This committee states the aim of secondary education in the paragraph at the top of page 6.

TABLE 1. AN ANALYSIS OF THE OBJECTIVES LISTED IN COURSES OF STUDY IN GENERAL SCIENCE*

TYPES OF OBJECTIVES	TIMES LISTED
A) Knowledge	
1. To acquire information about science	18
2. To acquire knowledge which will produce a better understanding of our environment	40
3. To acquire the knowledge necessary to correct superstition and erroneous beliefs	4
4. To acquire a scientific vocabulary	6
5. To acquaint the student with the source of scientific knowledge.	3
6. To acquire information concerning the lives of the great men of science	4
7. To acquire a body of facts which will enable one to read scientific literature	2
8. To acquire a knowledge of the fundamental principles of the subject	2
9. To acquire a knowledge of the application of principles in industry	3
10. To acquire the knowledge necessary for future courses in science or to prepare for college	6
11. To acquire knowledge which will function to secure the objectives stated in the bulletin on *Cardinal Principles of Secondary Education*	
a) Health	25
b) Citizenship	19
c) Worthy home membership	13
d) Vocation	12
e) Worthy use of leisure time	14
f) Development of ethical character	11
B) Exploration (or Orientation)	
1. To give the pupil a view of the field of science so that he may explore his interests, capacities, and abilities	9
a) as a basis for the election of further courses in science	8
b) as a basis for the selection of a vocation	9
c) to acquire new fields of interest	4
C) Abilities	
1. To develop the ability to think scientifically	44
a) to develop reliance on facts	5
b) to develop the power of interpretation	10

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* From *Instruction in Science*, Bulletin, 1932, No. 17. Monograph No. 22, United States Department of the Interior, Office of Education.

TYPES OF OBJECTIVES	TIMES LISTED
c) to develop the power of observation	19
d) to develop the ability to form independent judgments	12
e) to develop the ability to evaluate	3
f) to develop the ability to generalize	1
g) to develop the ability to locate problems	1
h) to develop the ability to plan prior to execution	1
i) to develop the ability to gather data systematically	2
j) to develop the ability to recognize defects and errors in conditions and processes	1
2. To develop the ability to use the scientific instruments common in the laboratory	4
D) *Attitudes*	
1. To develop a scientific attitude as shown by ability—	
a) to view facts objectively	2
b) to be free from dogma and superstition	2
c) to hold one's conclusion as tentative and to suspend judgment until facts are secured	3
d) to revise one's opinions if the evidence warrants	1
e) to have a spirit of inquiry	11
f) to be open-minded	12
g) to have a conviction of the universality of the cause and effect relationship	3
2. To develop attitudes of appreciation of—	
a) the contributions of scientific method	7
b) the contributions of science to mankind	20
c) the great men of science	8
d) expert judgment	5
e) nature	12
f) one's responsibility in the world	5
g) natural laws	4
E) *Ideals and Habits*	
1. To acquire ideals and habits of accuracy, persistence, honesty, self-control, truth, etc.	16
F) *Interests*	
1. To acquire an appetite for investigations in science	8
2. To acquire an appetite for scientific reading	9
3. To acquire an interest in taking more science	10
4. To acquire an interest in nature	10
5. To acquire interests in vocational fields	2
6. To acquire wholesome interests which may be used to enjoy spare time	14

> The purpose of general education is to meet the needs of individuals in the basic aspects of living in such way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society. Needs arise and work themselves out in living, dynamic events which can only be described as interactions between the individual and the social situation. . . . Thus when we speak of the need of the student to select and use goods wisely, we refer to a want (biological tension) or a desire on the one hand, and the requirements, demands, standards of social living on the other.*

The point of view of the committee is interesting in view of the controversy between the advocates of the "child-centered" curriculum and the believers in the "society-centered" curriculum. Advocates of the "child-centered" curriculum have demanded that learning activities be based upon the immediate felt needs or desires of pupils. Those who believe in a "society-centered" curriculum maintain that the business of education is to fit the pupil to live in an organized society. They believe that we should seek our objectives by a determination of the qualities, skills, abilities, etc., demanded for successful participation in this society. The demands of society should thus constitute the basis of our curriculum rather than the needs of pupils.

It is evident that the committee of the Progressive Education Association does not subscribe to either of the viewpoints. It rejects the "child-centered" curriculum because such a curriculum leaves out of consideration the demands of social living. It rejects the "society-centered" curriculum because such a curriculum neglects the biological tensions or wants of the individual. The committee believes that most situations have two aspects, personal and social; that the needs of the adolescent arise from an interaction between the individual and the social situation; and that the teacher must be concerned with the total situation, which includes both the individual and his environment.

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* *Science in General Education* (New York: D. Appleton-Century Co., 1938).

As a basis for the analysis and classification of needs the committee set up four centers of reference in terms of basic activities of living. These activities and the needs of adolescents to carry on these activities of living effectively are as follows:

A) PERSONAL LIVING
  1. The need for personal health
  2. The need for self-assurance
  3. The need for a satisfying world picture and a workable philosophy of life
  4. The need for a range of personal interests
  5. The need for esthetic satisfaction

B) IMMEDIATE PERSONAL-SOCIAL RELATIONSHIP
  1. The need for increasingly mature relationship in home and family life, and with adults outside the family
  2. The need for successful and increasingly mature relationship with age mates of both sexes

C) SOCIAL-CIVIC RELATIONSHIP
  1. The need for responsible participation in socially significant activities
  2. The need for social recognition

D) ECONOMIC RELATIONSHIP
  1. The need for emotional assurance of progress toward adult status
  2. The need for guidance in choosing an occupation and for vocational preparation
  3. The need for wise selection and use of goods and services
  4. The need for effective action in solving basic economic problems

The committee then considers the personal characteristics essential to democratic living. These are discussed in terms of the types of behavior that are desirable to foster. They include social sensitivity, tolerance, coöperativeness, the disposition and ability to use reflective thinking in the solution of problems, creativeness, self-direction, and esthetic appreciation.

To implement effective social participation and the realization of personal potentialities the individual must "understand the society in which he lives, the factors that are strategic in it, and the processes by which it operates and changes." The task of the curriculum-maker is therefore that of a search for the "understandings" that will bring about the desired changes in pupils. These understandings can be formulated in terms of the generalizations which when learned become incorporated in the individual as adaptations in personality resulting in intelligent behavior.

Each of these three reports has helped science teachers develop more clearly their views of the function of science in the education of boys and girls. It is in the light of these reports that the authors have selected the learning products, or objectives, aimed at in the *Science Problems* books. These objectives are as follows:

1. *An understanding of those generalizations of science that a citizen of a modern democracy needs in order to solve everyday* personal, social, and civic problems. Two criteria must be used in the selection of generalizations: (*a*) They must meet the needs of the pupils and the requirements of social living, and (*b*) they must be within the comprehension of most of the pupils who will take the course.
2. *An understanding and appreciation of the importance to oneself and to society of the applications of scientific generalizations and discoveries.*
3. *The development of a scientific attitude of mind.* One who possesses a truly scientific attitude has the following characteristics:

a) He has an inquiring turn of mind; he wants to know the what, the how, and the why of things.
b) He holds his conclusions subject to revision in the light of new evidence and revises those conclusions if the evidence warrants.

c) His judgments are as unprejudiced and as impersonal as possible.
d) He is careful and accurate in what he does.
e) He is free from dogma and superstition.
f) He is tolerant toward new ideas and suggestions.
g) He plans prior to execution.
h) He distinguishes between fact and opinion; he is slow to accept as facts, statements that are not supported by evidence.
i) He respects the judgments of experts.
j) He appreciates the value of science (both methods and subject matter) in living.

The development of a scientific attitude is a product of the method of instruction employed in the course. The teaching plan of the book, which employs the inductive method of approach to the major principles and generalizations and the problem method of organization, has as one of its major purposes the development of the scientific attitude.

4. *Growth in the ability to do critical thinking.* One learns to think by thinking. The activities, self-testing exercises, and problems to solve suggested in the course are of the type which demands reflective thinking. (An excellent analysis of reflective thinking and methods of encouraging reflective thinking is given in *Science in General Education.**)

5. *The development of wholesome intellectual interests and appreciations which lead to a desirable use of leisure time and which give a basis for educational and vocational guidance.*

The extent to which these changes take place in boys and girls through the study of science depends upon how skillfully the teacher directs the science activities toward their production. These objectives are not meaningless aims which should be read by the teacher and then forgotten. Each day's work should contribute to some extent to their realization. If this is to be the result, the teacher should know how each of the activities carried on by the pupils helps carry the pupil forward.

---

* *Ibid.,* chap. vii.

3. PRINCIPLES AND PLAN OF ORGANIZATION OF THE SERIES

Before describing the method of organization employed in this series, let us consider the study materials which have been commonly used in general-science classes. Consultation with teachers of junior high-school science and observation of work done in classes reveal that much of the reading material is too difficult for large numbers of the students. This difficulty appears to be the result of a complex of several factors.

Current Difficulties with Study Materials in General Science

1. *One cause of the difficulty of much general-science material is the method of organization employed.* The majority of general-science texts are organized almost entirely around environmental units or topics. When an environmental unit is presented, the generalizations of science needed to make the relationships within the unit clear are introduced when needed. In the earlier units of the course this makes necessary the introduction of an excessively large number of principles per unit, with the result that both the principles themselves and the environmental topics suffer.

To make clear the above statement, let us take a conventional unit on Weather. To develop a reasonable understanding of this unit, the following concepts and principles must be developed: temperature, radiant energy, reflection, absorption, evaporation, relative humidity, condensation, air pressure, convection currents, and the relationships of air pressure, temperature, and humidity in bringing about changes in weather. Now if we add the concepts dealing with thermometry, various forms of precipitation, areas of high pressure, areas of low pressure, isobars, isotherms, lightning, thunder, tornadoes, and weather prediction, we can easily see why such a unit is difficult. Environmental topics or units are naturally quite complex and involve a large number of relationships to interpret. Before such units are attempted, it would seem that some method must be employed to insure that a large number of the generalizations needed shall have been already developed.

Under the type of organization just discussed little if any provision is made for really teaching the principle to the point of functional understanding, that is, to the point at which the pupil can use the principle to interpret problems of a widely varying content. As a principle is introduced, application can be made only to the aspect of the environment being considered. If the principle is applied to the interpretation of any and all phases of the environment in which it supplies an explanation, the unit is thrown out of focus. For example, the idea of atmospheric pressure is introduced in the unit "Weather." It is needed to explain winds and their change in direction and in the prediction of the weather by the barometer. Now the idea of air pressure also explains how buildings are heated, pumps, vacuum-cleaners, non-skid tires, breathing, and innumerable other phenomena, devices, and processes. If we stopped, however, at this time, to use this idea to explain all of these things, weather would be entirely forgotten. The unit would be out of focus.

It is at this point that we get an explanation for the criticism of teachers that pupils do not learn the principles to the point where they will function. Really to learn a principle the pupil must practice using the principle as a method of explanation in all sorts of environmental situations. Through practice he acquires skill in analyzing situations to discover the problematic elements which determine the mode of attack and also skill in recognizing the situations in which the principle of science is the basis of explanation.

The introduction of a principle in an environmental unit results in ability to use the principle to interpret a specific situation relating to the unit at hand. Unfortunately, it does not transfer to other situations because it has not been generalized; that is, the pupil has not used the principle in a wide enough variety of situations to realize it and to accept it as a general mode of interpretation. He does not connect the air pressure which causes wind with the air pressure which operates a vacuum-cleaner or sends heated air upward from a hot-air furnace. They represent different things to him because they have not been associated in his experience.

The result of using principles only in the specific situations in which they are developed is a source of difficulty in later units. For example, a unit on water supply may follow the unit on weather. We need the idea of air pressure to explain the operation of pumps. We assume that pupils already have the idea because it has been presented in the weather unit. They do have the idea in connection with the specific situation encountered in that unit, but they have not really learned the principle, that is, developed it to the point of a general mode of interpretation. The teacher and the text assume that the idea is already understood; they therefore spend no time on it, and the result is that the new material becomes difficult because it assumes an understanding which is not present.

2. *Another source of difficulty is the encyclopedic treatment of concepts.* This difficulty arises in part from the fact that general-science courses cover an exceedingly large field. In order to present the vast number of concepts included in general-science courses, explanations have been condensed into as few words as possible. Psychologically this is unsound.

To make an idea easy it must be developed step by step, and this must be followed by a development of its implications. The logical outcome of such condensed encyclopedic treatment is mere verbalism. The pupil associates a principle with a series of words which have no meaning to him. It is no wonder that the principle does not become a part of his mode of behavior, that is, a method of explaining the world in which he lives. This is another difficulty that we must correct if we are to make the subject matter easier.

3. *A third source of difficulty relates to the style of writing.* This is in part the outcome of the encyclopedic method of presenting the concepts.

Other sources of difficulty are also found, but those discussed —organization of the units, encyclopedic nature of the treatment, and style of writing—are the most important.

Organization of the SCIENCE PROBLEMS Series

Our first step in trying to eliminate these difficulties was to analyze the environmental units to discover what principles and generalizations (understandings) of science were needed to secure intelligent behavior on the part of the pupil with respect to the aspects of environment treated in the series. This analysis provided a list of all the principles needed, and, more important than this, showed the extent to which each principle was needed as a method of explanation. The analysis showed, first, the frequency of use, and, second, the importance of the principle.

For example, an understanding of the nature of chemical change was needed in the following units of the series: How do we use and control fire? How are plants and animals alike? How do plants and animals get food? Why do we eat different kinds of food? How does the earth's surface change? How do we use energy? How do our bodies work? How can you help your body fight disease? How do we take care of the plants and animals we use? How do we make electrical currents? How do we use electrical current? How do we harness the energy of nature to do our work? and How can science help us keep from wasting nature's wealth?

Apparently in chemical change we find a fundamental concept that needs to be introduced early in the course and developed to the point of general functional understanding.

In a similar fashion it was discovered that concepts and principles relating to the nature of matter, the effect of heat upon matter, the cell structure of living things, the force of gravity, and the nature and use of energy were also basic to a large number of environmental units. It is apparent, also, that these concepts have an interpretive value in their own right quite apart from their relationships with other concepts in complex environmental units.

The authors therefore decided to take these fundamental concepts and principles and organize them into real teaching units. In these units the concepts and principles are carefully developed, and the pupil is shown how to use them to interpret a wide variety of situations. Through the use of exercises and problems he is given an opportunity to practice using the generalizations to explain problematic situations. In this way it becomes possible to teach the principle to the point of functional understanding, which, as we mentioned earlier, is extremely difficult if the course is organized solely on the basis of environmental units.

The reader will see the contrast between the two methods of development if he will read Unit 2 of *Science Problems, Book 2,* "How is the force of gravity useful to us?" Fifty-two pages are used for this presentation. In the conventional general science textbook the discussion of the principles related to gravity will be found scattered through many parts of the book. In no one place will there be found an adequate development of the generalizations needed to understand this vital aspect of our everyday surroundings. Similar units are developed for the other major concepts and principles listed in the fourth paragraph on page 13. These units are placed in the course to precede the environmental units for which they supply an explanation.

With a text organized in this fashion it becomes possible to develop environmental units as they should be developed. When we consider an environmental unit, the task is to show how the various phenomena, processes, and materials which constitute the environment are interrelated to provide the conditions and effects which the environment affords. Consequently, if we are to place our emphasis upon the interrelationship, the basic principles and concepts must be regarded as prerequisite to the unit. For example, the majority of books in general science present from thirty to forty pages on weather. At least three-fourths of this space is utilized to develop the principles and concepts mentioned on page 10. A correctly focused treatment would presuppose an understanding of the principles and would focus on an understanding of how the changes in relationship between air pressure, temperature, and humidity result in changes in weather.

It is true, of course, that some science principles and concepts must be developed in each environmental unit because only those of broadest application have been singled out for special attention in units focused directly upon them. But the number of principles so needed is reduced, making the environmental unit less difficult and making it possible to focus more directly upon the understandings of the unit.

One criticism which may be urged against the method of organization is that it is a return to the old "specialized-science" type of treatment. This, however, is not the case. The specialized-science treatment is essentially deductive in character. It presents a principle and then applies it. Let us contrast this with the method employed in this book.

In general the problems in these units start with one or more environmental situations. These situations are those common in the life of the pupil and pose the question, "How can we explain this?" Then the principle is developed through experimentation. The original situation is explained, several more environmental situations are presented, and the pupil is shown how to use the idea to explain these situations. In the Self-Testing Exercises and the Problems to Solve he is given other situations to explain by means of the principle. These afford the opportunity to practice using the principle. It is really during this practice that he generalizes and makes the idea his own. Thus the teaching plan is inductive-deductive in character. It starts with an environmental situation that presents a challenge to the pupil and ends in the use of the generalization to explain new environmental situations.

Another criticism which may be made is that the presentation of science principles and generalizations in "science" units rather than in "environmental" units is opposed to the idea that science should be "socialized." This raises the question, What is meant by "socializing" science? For example, how do we socialize Archimedes' Principle? Archimedes' Principle is socialized when it can be used by the pupil to carry on more effectively the activities of everyday living, or, more specifically, when it can be used in those situations in our environment which depend upon the use of Archimedes' Principle for explanation, for prediction of possible effects or inference of conditions past or present, or for deciding upon some course of action. This means, first, that the pupil be taught to recognize the kinds of situations that may be explained by reference to the relationships presented in the principle; second, that he be able to use this set of relationships to explain causes and effects involving this set of relationships; third, that he be given practice in using Archimedes' Principle to explain those aspects of his environment which are made clear by the principle.

The crucial step in socializing a science principle is in providing for the use of the principle in carrying on the activities of everyday living. The treatment of science principles in this series is such that it does provide opportunity for the pupil to use the principle for explaining, predicting, and doing.

The majority of pupils who will study *Science Problems, Book 3*, will already have studied most of the units in *Science Problems, Books 1* and *2*. For the teacher's convenience in surveying the content of the preceding books outlines are included.

PLAN OF SCIENCE PROBLEMS, BOOK 1

UNIT 1: How Do Scientists Work?
  Problem 1: How do scientists find problems?
  Problem 2: How do scientists solve problems?
  Problem 3: How have scientific instruments helped scientists solve problems?

UNIT 2: What Kind of World Do You Live In?
  Problem 1: What conditions surround us on earth?
  Problem 2: What materials do we find in our world?
  Problem 3: What living neighbors do we have?
  Problem 4: What natural forces do we use?
  Problem 5: What kind of body do you have?

UNIT 3: What Is a Material?
  Problem 1: How are all materials alike?
  Problem 2: What are solids, liquids, and gases?
  Problem 3: What is a solution?
  Problem 4: How are materials put together?

UNIT 4: How Do Heating and Cooling Change Materials?
  Problem 1: How do heating and cooling change the size of materials?
  Problem 2: What effect does heating have upon the state of matter?
  Problem 3: What happens to materials when they are cooled?
  Problem 4: How can we explain how heat affects matter?

UNIT 5: How Can One Kind of Substance Change into Another Kind?
  Problem 1: What are materials made of?
  Problem 2: How can we recognize a chemical change?
  Problem 3: How can we control chemical changes?
  Problem 4: What are two kinds of simple chemical changes?

UNIT 6: How Do We Use and Control Fire?
  Problem 1: What happens when things burn?
  Problem 2: How do we make fire?
  Problem 3: How do we regulate fire?
  Problem 4: How do we prevent and extinguish accidental fires?

UNIT 7: How Do Magnets Work?
  Problem 1: What will a magnet do?
  Problem 2: How can we make magnets?
  Problem 3: Why do magnetic compasses tell directions?
  Problem 4: How is magnetism explained?

UNIT 8: How Are Plants and Animals Alike?
  Problem 1: How are plants and animals alike in what they do?
  Problem 2: What chemical substances are living things made of?
  Problem 3: How are plants like animals in the way they are put together?

UNIT 9: How Do Plants and Animals Get Food?
  Problem 1: How do animals get food?
  Problem 2: How do green plants get food?
  Problem 3: How do plants that are not green get food?
  Problem 4: How do plants make food?

UNIT 10: Why Do We Eat Different Kinds of Food?
  Problem 1: Why do our bodies need food?
  Problem 2: What kinds of foods meet the different needs of the body?
  Problem 3: How can we select our foods wisely?

UNIT 11: How Do Plants and Animals Live Together?
  Problem 1: How do plants and animals depend on each other?
  Problem 2: How do social animals help each other?
  Problem 3: How is the balance of life maintained?

PLAN OF SCIENCE PROBLEMS, BOOK 2

UNIT 1: What is the Relation of the Earth to Other Heavenly Bodies?
  Problem 1: What is the earth?
  Problem 2: What is the solar system?
  Problem 3: What is the nature of the universe?
  Problem 4: How do the earth's movements affect us?
  Problem 5: How do astronomers learn about the heavenly bodies?

UNIT 2: How Is the Force of Gravity Useful to Us?
  Problem 1: What effects does gravity have?
  Problem 2: How do we use gravity to measure materials?
  Problem 3: How does gravity affect liquids?
  Problem 4: How do we use the pressure of the atmosphere?
  Problem 5: How does the force of gravitation differ at different places?

UNIT 3: How Does the Earth's Surface Change?
  Problem 1: How are rocks changed into soil?
  Problem 2: How are materials carried from place to place?
  Problem 3: How do volcanoes change the earth?
  Problem 4: How are mountains formed?

UNIT 4: Why Do Some Things Rise and Others Sink in Fluids?
  Problem 1: Why do some objects float and others sink?
  Problem 2: How does gravity cause water and air to circulate?

UNIT 5: How Do We Use Energy?
  Problem 1: What is energy?
  Problem 2: What do we do with energy?
  Problem 3: What are the different forms of energy?
  Problem 4: How do we change one form of energy into another?

UNIT 6: How Do We Control Heat?
  Problem 1: How does heat travel from one place to another?
  Problem 2: What happens to heat when a material changes from one state to another?

Problem 3: How do we keep our buildings warm?
Problem 4: How do we keep things cool in warm weather?

UNIT 7: What Makes the Weather Change?
Problem 1: What causes the different kinds of weather?
Problem 2: Why does the weather change from day to day?
Problem 3: How are weather forecasts made?

UNIT 8: How Do Our Bodies Work?
Problem 1: How is your body put together?
Problem 2: How do our cells keep alive?
Problem 3: How does blood move through your body?
Problem 4: How does your food dissolve and get into your blood?
Problem 5: How does your blood get oxygen and get rid of carbon dioxide?
Problem 6: How does your body get rid of its nitrogen wastes?

UNIT 9: How Can You Help Your Body Fight Disease?
Problem 1: What are disease germs?
Problem 2: How do germs make us sick?
Problem 3: How do our bodies fight disease?
Problem 4: How can we help our bodies fight disease?
Problem 5: How can we help prevent the spread of disease germs?

UNIT 10: How Does Life Continue on the Earth?
Problem 1: What are some of the ways in which living things reproduce?
Problem 2: How do seeds grow into plants?
Problem 3: How do animals grow?

UNIT 11: How Do We Take Care of the Plants and Animals We Use?
Problem 1: How do farmers improve their soil?
Problem 2: How do we protect our plants and animals from their natural enemies?
Problem 3: How do we select food for our animals?
Problem 4: How do we provide proper housing for our animals and plants?

It is evident from the preceding outlines that *Books 1* and *2* present a number of concepts basic to *Book 3*. These concepts are reviewed briefly where they are first needed in *Book 3*, but the teacher should be prepared to give special emphasis to the review, especially when the class includes pupils who have not studied *Books 1* and *2*. In this connection a few copies of *Books 1* and *2* in the classroom or library will be very useful.

To complete a well-rounded science course, the units of *Book 3* are needed. The preview given below describes briefly the units that are developed with the concepts and principles of *Books 1* and *2* as a background.

PLAN OF SCIENCE PROBLEMS, BOOK 3

Although *Science Problems, Book 3*, is the terminal book of the three-year series, the major part of the material in it is not in its details directly dependent on the material of the two preceding books. Certain broad understandings are assumed to have been derived from *Books 1* and *2*, as, for example the cell nature of all living things, the mechanics of reproduction and growth, and the nature of energy and force. However, each of the twelve units of *Book 3* is the initial treatment of the topic covered by it. These units were allocated to the third book of the series as the result of careful consideration of their fitness in the social and mental maturity of the pupil and of the inherent difficulty of the science concepts involved in them.

The book opens with three biological units, each of broad basic significance in any intelligent attitude toward the environment. The first of these three—*How do living things behave?*—is not only broad in its significance but intensely personal. It will probably be the student's first acquaintance with the problem of "Why we behave like human beings" and should serve him as the beginning of an intelligent attitude toward his all-important mental and emotional life. Students in ninth grade are usually in the midst of that distressing experience known as adolescence. The material of this unit, if wisely handled, can do much to clear up the confusions and disturbances of that period.

As befits the level of maturity of the learner, the discussion is kept at an elementary level. The physiology of the nervous system is only lightly touched upon. In rather unacademic manner the unit plunges directly into the problems of human behavior, instead of beginning with the ameba and progressing on up to man. The broad significance of behavior throughout the world of living things is reserved to the latter part of the unit. Thus the unit itself, and the book as a whole, opens on a note of distinctly personal import to the pupils.

Twenty or twenty-five years ago the intricacies of the Linnaean system were scarcely ever even heard of outside academic halls, much less discussed. Today, curiously enough, terms used in the scientific classification of plants and animals are becoming more and more frequently heard and used. The prominence given in the daily press to scientific discovery in the field of biology, the awakened interest in the out-of-doors, and the widespread growth of garden clubs, even among men, may perhaps in part account for growing public familiarity with technical plant and animal names which a few years ago were part of the language only of biological scientists. Thus, Unit 2, *How do scientists classify living things?*, presents ideas which should be a part of the cultural equipment of an intelligent citizen. But even more important in the unit is the picture of the systematic method of the scientist and the idea that to utilize knowledge, this knowledge must be organized in orderly fashion. The unit furnishes background material for Units 10 and 11.

The third unit of the book, *How are plants and animals fitted to the conditions around them?* furnishes an elementary acquaintance with that essential of living—adaptation to the physical environment. Almost all of biology could be taught in terms of adaptation, and there is a wealth of material for observation everywhere in the out-of-doors. This unit supplies especially pertinent background material for Units 10 and 11.

Unit 4, *How do simple machines help us do work?*, begins a series of six units devoted to the physical sciences and focused largely on man's use of energy. As a prerequisite to this study of power and power machines, Unit 4 introduces the pupil to those simple machines by which man first multiplied the force of his muscles and which are the units of construction of the complex machines that do so much of the world's work today. Also, the pupil becomes acquainted with the scientific meaning of "work" in clarification of the function of the simple machine and in anticipation of the discussion of horse-power in Unit 9.

Electricity, the energy that runs so many of our machines, is treated in two separate units because of the great number of new ideas inherent in the topic. Unit 5 is devoted to the production and control of electrical currents—the nature of electrical charges, electrical wiring, cells and batteries, and generators.

To avoid possible monotony from too long attention to the study of electricity, the units on sound and light are interposed between the two electricity units. Sound, the medium of by far the greater part of the world's communication, is the subject of Unit 6. In addition to a thorough discussion of the nature of sound—its production, reproduction, and control—the unit deals with musical instruments and with the structure and care of the ear.

Light energy is the topic considered in Unit 7. The discussions of mirrors, lenses, color, home lighting, and the care of the eyes make this unit of great practical value and interest to the pupils. Much of the unit will probably be quite novel to them; refraction, absorption, lenses, and color, while everyday phenomena, are usually not at all understood by pupils prior to their study of science.

Electricity is taken up again in Unit 8, which is devoted to the absorbing and very practical topic of how we use electrical current. Heating pads, flatirons, light bulbs, neon tubes, motors, transformers, telephones, telegraphs, radio, and television are typical of the practical aspects of this unit.

The six units of physical science close with Unit 9, which is given over to the study of power machines—water-wheels, steam and water turbines, steam engines, internal-combustion engines, transmission of harnessed energy, and future sources of energy.

Such topics demand the fullest mental and social maturity on the part of the learner; hence they have been placed late in the series.

In the last three units the learner is again taken to the world of biology. Unit 10 presents a quite elementary but nevertheless very significant picture of heredity. The unit plunges directly into the problem of why children look like their parents, and throughout the unit the discussion is always tied up closely with everyday problems of the home, the garden, and the farm.

Few fields of scientific investigation so challenge the interest of the layman as that of the origin and development of living things on the earth. "Dinosaur" has become almost as common a word as "cat." Unit 11 introduces the pupils to the fascinating story of the earth's history as told by the rocks. Such a unit needs no justification from the standpoint of practicality, nor should such justification be sought. The culture of the race demands an intelligent understanding of what scientists have discovered about the origins of our living and non-living world.

The values and functions of the closing unit (conservation of soil, fuels, wild life, and forests) need no explanation. Indeed, it is unfortunate that so little space could be allotted to this all-important topic. While the significance and seriousness of conservation from a national standpoint are thoroughly stressed in the unit, the teacher will quickly see the wealth of opportunities for local application of the principles brought out in the unit.

INTERNAL ORGANIZATION OF THE UNITS

INTRODUCTORY EXERCISES. At the beginning of each unit is a series of Introductory Exercises. These exercises have four purposes: (1) They serve as a basis for recall of previous knowledge or experiences which may be of value in the study of the unit. (2) They enable the teacher to pick out the students who are poorly equipped to enter upon the study of the unit because of inadequate preparation or lack of experience with nature. (3) They enable the teacher to select the parts of the unit which

may be of general difficulty to the whole class. (4) They stimulate interest in the new unit.

LOOKING AHEAD. This part of each unit is developed in a variety of ways but always has three important purposes: (1) to help the pupil see what the unit problem really is, (2) to make the pupil feel and understand the importance of the unit to him, and (3) to arouse an active interest in the study of the unit.

PROBLEMS AND SUB-PROBLEMS. Each unit is divided into major problems focused on the larger concepts to be developed in the unit. Each problem is further divided into sub-problems focused on minor concepts essential to an understanding of the major problem. It should be noted that the problems and sub-problems are focused on understandings which have interpretive value. The subject matter presented in the problems and sub-problems is the assimilative material or the data used by the pupil to arrive at an understanding.

SELF-TESTING EXERCISES. The Self-Testing Exercises are of two types: those testing the pupil's comprehension of the generalizations developed and those testing his ability to use the generalizations to interpret or explain problematic situations. They provide practice in using the idea.

PROBLEMS TO SOLVE. The Problems to Solve are designed to give the pupil practice in using the ideas to interpret more complex situations than those included in the Self-Testing Exercises. As such, they require a greater depth of thinking and provide opportunities for the brighter pupils. They also call for additional reading, observation, collecting, and experimenting.

LOOKING BACK. The type of summary exercise varies from unit to unit, but each has the same general purpose: that of requiring the pupil to look back over the unit, select the important ideas, and state them in concise and organized form.

ADDITIONAL EXERCISES. These exercises provide supplementary activities and problems which require further investigation for solution. They suggest projects and experiments of various kinds which may be carried out. On pages 713-720 of the text is a list of readings which may be used in this connection.

4. SUGGESTIONS FOR FITTING THE COURSE TO LOCAL CONDITIONS

The authors have selected and arranged their material with great care. Where classes meet every day and the periods are not too short, each book presents an excellent year's work. When the classes meet only two or three times a week or the background and abilities of the pupils are below average, study of an entire book will probably require too superficial a treatment. In such cases it will be better to modify the course by omissions and varied treatment of units than to hurry through all of them. The teachers in each school or school system should study their own situation and choose with care the material to be taught.

Because of the interdependence of units, selections and omissions require careful examination of the sequences that have been built into the books. To assist teachers in scheduling the units and in making necessary selections of content Table 2 has been prepared. The time schedule presented in the fourth column of the table is arranged to fill 34 weeks. This is about the amount of time that will be available for teaching in a school with a nine-month term. The schedule will, of course, vary when units or parts of units are omitted. The actual amount of reading of content material and of directions for experiments is indicated in the fifth column. This quantity, together with the number of experiments to be done, is used to determine, in general, how much time will be needed for the unit in relation to the other units to be taught.

The last two columns of the table are intended to be helpful when the course must be modified for any reason. The last column indicates variations that can be made. In connection with this column it should be kept in mind that the more able pupils can often be led to study or at least read parts of a book that are not included as required work for all pupils. The second column from the right indicates what material in the book should have been studied before each unit is taken up.

TABLE 2. SUGGESTED TIME SCHEDULE FOR TEACHING SCIENCE PROBLEMS, BOOK 3

UNITS	*PAGES OF READING	NUMBER OF EXPERIMENTS	TIME-ALLOTMENT IN WEEKS†	COVERAGE PER WEEK		BACKGROUND MATERIAL IN PRECEDING UNITS	POSSIBLE MODIFICATIONS IN TREATMENT
				Pp.	Exp.		
1. Behavior	42	4	3	14	1+	Biological material in Books 1 and 2 useful but not essential	May be read and discussed with few or no written assignments. May be used later in year.
2. Classification	39	2	3	13	1−	Book 1: Units 8, 9 Book 2: Units 8, 10	May be used later in year. May omit Prob. 5.
3. Adaptation	29	0	2	14+	0	Book 1: Units 8, 9 Book 2: Units 2, 4, 6, 8, 9	May be used as reading unit or later in year.
4. Simple Machines	31	5	3	10+	2−	Book 2: Unit 5	May be used as reading unit except Prob. 2 (needed for Unit 9).
5. Making Electrical Currents	33	9	3	11	3−	Book 1: Units 5, 7 Book 2: Unit 5	
6. Sound	37	10	3	12+	3+		May be used as a reading unit.
7. Light	32	9	3	11−	3		May be used as a reading unit.

8. Using Electrical Current	36	7	3½	10+	2	Book 1: Unit 7 Book 2: Unit 5 Book 3: Units 5, 6 essential	
9. Harnessing Energy	36	3	3½	10+	1−	Book 1: Unit 6 Book 2: Units 4, 5, 6 Book 3: Units 4, 5, 8 essential	
10. Improving Plants and Animals	27	0	2	13+	0	Book 2: Unit 10 Book 3: Unit 3 very desirable	
11. History of Living Things	30	0	2½	12	0	Book 2: Unit 3 Book 3: Unit 2 essential, 3 desirable	May be used as a reading unit or omitted.
12. Conservation	34	0	2½	14−	0	Book 1: Units 6, 11 Book 2: Units 3, 11 Book 3: Unit 9 essential for Prob. 2	
Total	406*	49	34	Average			
				12−	1½−		

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*Exclusive of pictures, legends, and exercises. Including experiments and tables.

†Assumes school year of 34 weeks.

Suggestions for omitting certain units should not be taken as indicating lack of importance of the material. Necessity may require that the time spent on the course be reduced. In such circumstances it is better to omit some content or to use it for supplementary reading than to "cover the ground" at a rate which reduces interest, destroys the scientific attitude, and makes training in scientific thinking virtually impossible.

5. TECHNIQUE OF INSTRUCTION

The plan of organization of this book makes it possible to use any of the commonly accepted methods of teaching. It is a "unit-plan" book and as such is focused on the attainment of functional understandings. The assimilative materials necessary to develop these understandings are contained in the book and may be used by the teacher in any way he thinks desirable.

In the past fifteen years there has been a tremendous spread in the use of what is called the unit method of teaching. In this method of instruction the teaching is divided into five phases: (1) exploration, (2) preview, (3) assimilation, (4) organization, and (5) recitation. While this plan of teaching is not a necessary concomitant of the method of organization of this book, a brief statement of the technique is included here because of the many requests of teachers.

EXPLORATION

The purpose of this phase of the work has been discussed in the paragraph on "Introductory Exercises," page 23. Experience has indicated that it is a good plan to have the pupils write out the answers to the Introductory Exercises so that an individual diagnosis is possible. It is not expected that the students will be able to answer all questions correctly. Some of the exercises are based on the study material in the text. A few pupils may have progressed much farther than the average, and if their answers to the Introductory Exercises show that they thoroughly understand certain parts of the unit, they may be allowed to work on the Additional Exercises or projects.

Some teachers discuss the answers to the Introductory Exercises after they have been written. If this practice is followed, care should be taken not to discuss those exercises that are based on the new study material. The exercises which are answered in the unit and which should not be discussed will be evident from an examination of the text. After the papers have been examined by the teacher, they may be returned to the pupil at the end of the work on the unit with the incorrect exercises marked. The pupils may be instructed to correct their answers when they have completed their study of the unit. Such practice will reveal to the pupil the progress he has made and his change of viewpoint during his work on the unit.

PREVIEW

The purpose of the preview has been discussed under the section, "Looking Ahead," page 24. The preview may be presented in the form of a 15- or 20-minute talk by the teacher; that is, the teacher may read the "Looking Ahead" section as given, outline it, bring in additional illustrations of his own, and then present it in the form of an informal lecture. The introductory comments for each unit will also serve to suggest the content of the teacher's talk as an introduction to the unit. There is a wealth of historical material which may well be brought into the preview of the unit. Progress in the development of man's control of some phase of the environment supplies an excellent background upon which to project his present state of control and serves to indicate further advances which may be made. It is suggested that the teacher supplement each preview with additions of this kind. Space limitations made it impossible to present as much of the historical material in the previews as the authors think would be advisable.

If this method is followed, the pupils listen to the talk, and at the end of it are required to write out their own idea of the unit as obtained from the talk. This gives valuable training in listening and in written expression.

Another plan is to have the pupils read the "Looking Ahead"

section and then outline it. This will insure that they see the unit in its entirety and that they see the relationship of the problems and the contribution of each to the unit. Some teachers may wish to use a diagram of the unit similar to the unit graphs in this manual. Whatever method is followed, care should be taken not to include details in the preview. In his study of the unit the pupil will undertake to round out the general ideas brought out in the preview and answer the questions inspired by it.

It has been observed in some classrooms that teachers follow the presentation with a true-false test on the facts presented. This procedure does not usually follow out the idea of the presentation. It tends to become a test of what the pupil remembers of the factual statements made in the presentation. Such a method is simply a test of what the pupil remembers of what the teacher said. The primary function of the presentation is orientation. The most significant test is, "What are the problems which you will try to solve in this unit?" The answers to this question will show the teacher whether or not the pupils have caught the general idea of the unit. The answers will show whether or not the general plan of the unit is grasped; in other words, whether or not the pupils are correctly orientated.

Three general types of learning activities are employed.

a) *Listening to the spoken word.* This activity involves the ability to follow through a talk without losing the train of thought. To do this, one must be able: (1) to pick out important points, (2) to recognize that illustrations and examples are used *to clarify the speaker's thought and are minor details,* (3) to concentrate on what the speaker says, (4) to make a mental summary of the main points as the speaker talks, and (5) to learn to identify different methods of organization used. After the talk the pupil must be able to recapitulate the main points. This he will ordinarily do by making an outline of the main points, keeping them in sequence, and then filling in the details.

b) *Taking notes on talks.* In taking notes the same activities are involved as in listening. In addition, however, the pupil

TABLE 3. SCHEME OF INSTRUCTION TECHNIQUE

STEPS IN THE LEARNING PROCESS	STEPS IN THE CLASSROOM TECHNIQUE	STUDENT ACTIVITY INVOLVED	TESTING RESULTS
Stimulus or Motivation or Seeing the problem	Exploration (1)* or Pre-test Review previous work Recall experiences pertinent to unit	Discussion and written work	Questions and exercises
	Preview (1) Teacher's sketch of unit—15 to 20 minute talk with simple demonstrations	Listening, observing, note-taking, or Reading preview in text	Written or oral composition on preview
Study (directed) or Reflection or Solving the problem	Individual or group study (5–20)	Reading Extensive Intensive Experimentation Field trips Drawing Observation of motion pictures Observation of demonstrations Demonstration before class Responses to exercises	Oral quizzes Written quizzes Composition True-false tests Completion tests Best answer Summaries Reports on experiments Discussion before class Interpretation of new situations Self-testing exercises Problems to solve
Reaction or Application or Use of knowledge	Organization (1–2)	Preparation of outline, summary, or syllabus of unit	(The activity is itself the test.)
	Recitation (1–2)	Oral and written recitation	(The activity is the test.)

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* The numbers in parentheses following steps in classroom technique suggest the approximate number of periods to be given to each step.

must learn to write words or short phrases which will help him recall the main points of the talk. The most common error in taking notes is that the pupil will try to write everything the speaker says. This is of course impossible, and the pupil soon loses the train of thought. A good method of teaching note-taking to young students is to present part of the preview involving one main idea; then stop and show the pupils what notes they should have taken. This may be repeated until they catch the idea and are able to take notes on a talk lasting for twenty or thirty minutes.

c) *Observing motion pictures.* Sometimes the best way to get an overview of the unit is by use of a motion picture. When used for this purpose, the film should be run and followed by a discussion in which the questions or problems raised by the film are listed. These should not be answered at this time but should serve as a basis for introducing the problems of the units.

ASSIMILATION

In this phase of the work the learning activities of the pupil himself are the major concern. Through his own activity he is to gain an understanding of the problems of the unit. To guide the pupil in his study during the period of assimilation, the authors have broken up the main problems into sub-problems. These sub-problems focus the attention of the pupil on the important sub-ideas necessary to solve the problem. The great help given by the sub-problems can only be appreciated by comparing this type of organization with the conventional topical heading. The material included under each sub-problem is definitely focused on the solution of the major problem. In the majority of texts it will be found to be impossible to word the topics in the form of sub-problems and then find the material included to provide a solution for the problem.

The study material proceeds step by step, raising questions, introducing facts and principles through reading and experimentation when an actual need for them is felt. In other words, the method of teaching is inductive and is incorporated into the

study material. It is essential that each pupil solve the problem for himself, since it is through his own activity that understanding is finally reached. Fundamentally, a textbook should be regarded as a source of data for solving problems. It presents the assimilative materials which may be used to arrive at certain understandings; therefore, memory of the assimilative materials is not the end product of a course. These materials are merely a means to the end. When teaching a given unit, the teacher has in mind certain understandings, abilities, attitudes, and interests upon which the assimilative material should focus. The question is, therefore, "What activities shall I have my pupils carry on with these assimilative materials to accomplish my objectives?" The assignment (the activities set up by the teacher) is therefore the crucial factor in determining the learning products that will result.

There are many types of learning activities. Certain types are best adapted for certain kinds of learning. The teacher's task is to select that type of activity most likely to be successful in bringing about the desired result. In science a large part of the learning is essentially a process of acquiring meanings. When a thing, a situation, or an event has acquired meaning, it is understood. Perhaps the best statement of this idea has been given by Dewey: "To grasp the meaning of a thing, an event, or a situation is to see it in its relation to other things, to note how it operates or functions, what consequences follow from it, what causes it, and to what uses it can be put."

If we follow Dewey's idea, we can see that we need a variety of learning activities focused on each understanding, so that the idea may be approached from many angles. The book provides some of these angles of attack. Discussion in class can be most advantageously carried out if you formulate learning activities which attack the idea from a different angle. The more difficult the idea, the greater the number of types of learning activities that must be employed. Using a different set of learning activities for discussion from those given in the assignment also results in more thinking and greater interest.

To assist the teacher in formulating different types of learning activities, the following list is provided. When you make an assignment or prepare activities for classroom discussion, glance through this list and find appropriate types of activities. An example of each type of activity is included.

One of the objectives of an introductory science course is that of acquiring certain skills and abilities. To realize this objective, activities must be provided involving these skills and abilities, the attention of the pupil must be fixed upon correct methods of procedure, and sufficient practice must be given for the pupil to attain them. The following discussion therefore will consider some of the types of activities provided for in the *Science Problems* series and also give some suggestions for teaching pupils how to carry on these activities.

1. STUDY READING. Reading for study is of an analytical nature. The following method is suggested for this book:

a) *Read with a definite purpose in mind.* This requires a thorough comprehension of the problem to be solved. The pupil's question to himself should be "What am I trying to find out?" To test his comprehension of the problems, the student should frame it in his own words. Most pupils look upon study as learning what the text says. That is not the attitude desired in science.

b) *Read through the entire problem to get a general idea of the whole, always keeping in mind the question which you are trying to answer.* Stopping to clear up obscure points or to look up new words wastes time, because in a great many cases these will be cleared up by further reading of the problem. This first rapid reading will also furnish the pupil a basis for judging the relative importance of the different parts of the subject matter, which will assist him in distributing his time. He should look especially for sign-post or summary paragraphs and topic sentences. Pupils have become so used to studying carefully everything they read that it is sometimes difficult to get them to do this type of reading. Pupils of this age ought to read about 250 words per minute, which is about the number of words per

page. To get them to understand how you want them to read, set a time limit; that is, if the problem is five pages, give them five minutes to read it. This time varies with different classes, and the teacher can by experiment determine the best rate for each class.

c) *Reread the problem more carefully.* In this step the pupil should make a careful analysis of the subject matter. The following directions will assist pupils in this analysis:

1) Keep the problem constantly in mind and examine the subject matter in light of this problem.

2) Note carefully italicized words. These words are new words and are defined in the text. Be sure that you understand their meaning before you go on.

3) Try to picture in your "mind's eye" or make a sketch of the materials or articles described.

4) Try to relate the material to something which you already know.

5) Try to determine why the writer went from the first point to the second, and so on.

6) Use the illustrations. Each illustration or diagram was put in the text for the purpose of helping you understand more easily. Ask yourself "What does this picture show?"

7) Make in your own words a topical sentence for each paragraph. Remember that each paragraph has some one idea necessary to the understanding of the whole and that all of these ideas will furnish an outline of the problem.

2. OBSERVING MOTION PICTURES. Motion pictures provide another way of getting experiences. They should be just as carefully selected to fit into the unit or topic being studied as a demonstration or reference would be. Motion pictures are of special value as means of assimilation when it is desirable (1) to extend experiences with industrial processes or natural phenomena that are inaccessible because of time and space limitations, (2) to show phenomena and processes that are not easily observable, (3) to explain and clarify by animated diagrams, and (4) to vitalize the work.

There are certain principles of using films which have demonstrated their values:

a) The "build up" or preparation should be just as carefully carried out as for a key demonstration unless the film itself carries such a "build up."

b) The teacher should try to develop an atmosphere that will lead to the seeing of the picture as an interesting and enjoyable learning experience rather than a piece of pure entertainment or as a basis for a quiz on all of the details, which may kill the pleasure and satisfaction of seeing the film.

c) Whenever practicable, the film should be shown in the regular classroom to maintain a normal atmosphere rather than a "show" atmosphere.

d) At the first opportunity after showing the film, pupils should be given a chance to ask questions. The teacher may often start quizzing and let pupils carry on as soon as they begin asking questions.

e) After the picture has been run, use its content. Ask questions that can be illustrated or explained by what was seen in the picture.

f) After a discussion both of the picture and of the related material in the unit, it is often advisable to raise questions which are answered in the film but which were not made clear at the first showing. The film should then be re-run for this purpose.

3. LISTENING TO EXPLANATIONS. It is often advisable to supplement the study material with explanations by the teacher. Occasionally the explanation is best given before the pupils study, but as a rule the explanation should be supplementary rather than introductory. In such explanations teachers should make abundant use of the blackboard for diagrams and outlines.

If the explanation involves processes which split into different parts or phases, it is good practice to stop at the end of each phase and ask for questions upon parts that are not clear. Pupils should be made to feel that it is their responsibility to ask for further information if the explanation is not clear. If the ex-

planation is followed by a written question involving the use of the idea presented, pupils are more likely to take the responsibility seriously because they know that an explanation is followed by a quiz.

4. OBSERVING EXPERIMENTS. In observing an experiment the pupil should ask himself "What is the purpose of this experiment? What results are obtained? What conclusions can be drawn?" Younger students quite frequently look upon the manipulation of the apparatus as the end of the experiment and fail to realize that the experiment has been performed for the purpose of providing data for the answer to some question. To obtain this questioning attitude, the teacher should allow each member of the class to formulate his own conclusions. If the teacher states the conclusion, the members of the class will get into the attitude of focusing their attention on the manipulation of the apparatus, knowing that when the experiment is over, the teacher will explain it.

5. PERFORMING EXPERIMENTS IN THE LABORATORY OR FOR DEMONSTRATION. Since the method of the book is inductive in character, the experiments are introduced when data are necessary for the solution of the problem. Laboratory work is therefore not an end in itself; it is, rather, a step in problem solving. Where separate class periods are designated for laboratory work, the teacher should precede this work by a class discussion of the problems for which the experimental data are to be obtained.

If the laboratory work is to be of value, it must be carefully supervised. The pupil should:

a) know the purpose of the experiment;

b) make a careful analysis of the apparatus to be used (if necessary, an analytical drawing should be made);

c) watch everything that happens and see how it is related to the purpose of the experiment;

d) see how one step is related to another—the relation of cause to effect;

e) formulate conclusions on the basis of observed results;

f) apply his conclusions to the problem in hand.

The following directions to pupils have been found helpful in teaching them how to experiment:

a) Before you do an experiment, you should have clearly in mind the purpose of the experiment, that is, the problem you are to solve. This is necessary so that you may understand why the experiment is done in a certain way. It also helps you to get clearly in mind the nature of the facts that you are trying to discover. Ask yourself questions such as these: What is the purpose of this experiment? What am I trying to discover?

b) Next, you should read the entire experiment through to find out (1) how the experiment is to be performed, (2) the purpose of each part of the experiment, and (3) the kind of observations you are to make. Many students make the mistake of reading an experiment line by line, doing what the directions say. *When they get through, they do not know what they have* done because they have not kept clearly in mind exactly what they were trying to find out.

The best method is to read the experiment all the way through and then ask yourself: What is the first thing I am to do? What will I find out if I do this? What is the second thing I must do? etc. Another question to ask is, "Why is this method used in the experiment?" If you are going to learn to experiment for yourself, you must find out why scientists experiment the way they do.

c) Now you are ready to do the experiment. Follow directions *exactly*. Sometimes, of course, you may have to use slightly different apparatus from that called for, but the procedure should be followed with great care. The first lesson that you should learn about experimentation in science is accuracy.

d) Next, consider what you have learned from the experiment. In other words, what are the results that you obtained? "What did I discover from doing this experiment?" is a good question to ask.

e) Now you are ready to draw your conclusions on the basis of the facts you have collected. Your conclusions should answer the purpose in your mind when you began your experiment.

6. TAKING FIELD TRIPS. One of the most important types of learning activities in science is that of obtaining direct, first-hand contact with the materials, forces, things, processes, and phenomena of our daily environment. To a very great degree learning in science must be based upon perceptual experiencing. We may bring materials into the classroom for the pupils to observe, or we may perform experiments, but in each of these cases we are taking the thing or process, etc., out of its environmental setting. Really to understand a thing or a process we must see it in its natural setting; we must see it in its relationships to other forces, things, materials, and processes. For this reason field trips should be taken whenever and wherever possible.

There are certain principles of accepted practice that may be useful to the beginning teacher in planning field trips:

a) No field trip should be conducted without a definite purpose in the mind of both teacher and pupils. The teacher must decide ahead of time exactly what data are to be obtained on the trip.

b) The teacher must visit the places to be observed before the trip is taken so that he knows exactly what is to be seen, the location of the specific points of observation, and the order in which the observations are to be made.

c) The pupils should understand what a field trip is for and have the proper attitude toward it. They should see that things can be learned on field trips which cannot be learned from books, that on field trips they see things as they really are, and that they must know what to look for as they make their observations. They must understand that they are to keep together, that they must not talk while the teacher is talking, and that they should ask questions if they do not see what the teacher is talking about.

7. SOLVING THE SELF-TESTING EXERCISES AND THE PROBLEMS TO SOLVE. It has been found that the attention of the pupils can be most effectively focused upon the important concepts presented in the book through one or more Self-Testing Exer-

cises on each problem. Thus the Self-Testing Exercises are a very important part of the study of the problems in each unit. They serve the following important purposes:

a) Test the pupil's understanding of the problem up to that point.

b) Inform the pupil whether or not he is ready to proceed and can understand that which follows.

c) As an integral part of the study material, often refer to illustrations and to the text and thereby furnish links between what precedes and what follows.

d) Give the teacher objective evidence of the progress of each pupil.

e) Emphasize the important concepts necessary to an understanding of the unit.

f) Furnish a definite basis for self-activity.

g) Give the pupil training in measuring his own accomplishment.

h) Provide for a large number of intellectual activities of the types used in the scientific method of study.

Because of the importance of the proper use of these exercises in the correct methods of study, the teacher should see that they serve as many of the purposes listed above as possible under the teaching situation in his classes. The Self-Testing Exercises should be done by all pupils in the class. They can all be solved by proper use of the data contained in the text.

In addition to the Self-Testing Exercises, Problems to Solve have been provided. They include a wide range of activities which in general require a greater depth of thinking than the Self-Testing Exercises. As a rule, the emphasis is upon the use of the idea in explaining some environmental situation, in predicting results which follow certain conditions on the basis of science principles, or upon using the ideas to carry on some practical activity. They also include activities that are focused upon an extension of the ideas presented in the text.

The Self-Testing Exercises and Problems to Solve include the following different types of learning activities:

1. Examining a series of specific cases to arrive at a concept of class. (*What are the characteristics of a chemical change?*)

2. Examining a series of specific cases to arrive at a concept of relationship. (*How does the work put into a machine compare in amount to the output of the same machine?*)

3. Selecting facts on a given basis. (*Name three substances that are very elastic.*)

4. Judging the adequacy, relevancy, correctness of conditions, factors, statements, etc. (*In what respects does your local water supply meet the requirements of a good water supply? Criticize the following statement: Frost is frozen dew.*)

5. Comparing two processes, events, etc., to arrive at a concept of likeness and differences. (*In what ways is the human body like and unlike a machine? Compare a steam engine with a gasoline engine.*)

6. Arriving at a judgment of the relative values of two or more devices, theories, etc. (*Which kind of fuel is best for the average small home? Which theory of the origin of the solar system best explains the facts?*)

7. Experimenting. (a) To determine effect produced. (*Determine by use of an iron ball and ring the effect of heat upon a metal.*)

b) To evaluate. (Which is the better conductor of heat—copper, or iron?)

c) To discover relationships. (*How does the amount you can lift with a lever change when the force-arm is lengthened?*)

d) To verify principles. (*Perform an experiment to verify Archimedes' Principle.*)

e) Formulating plans for original experiments. (*Plan an* experiment to find which of two vacuum bottles is the better.)

8. Observing. (Observe the direction and length of your *shadow at different times of the day.*)

9. Discussing and summarizing, involving the selection and organizing of material. (*Discuss Law of Conservation of Energy.*)

10. Outlining. (*Make an outline of the reading material on how the balance of life is brought about.*)

C. B. T.

11. Explaining. (*Explain why the ticket-taker on a merry-go-round leans in toward the center. Why does a region of low pressure bring rain?*)

12. Making models or devices. (*Make a waterproof sand table in which your class can see erosion occurring.*)

13. Verifying. (*Cite evidence to show that typhoid fever is caused by a germ.*)

14. Dramatizing. (*Write the directions for three people who are to demonstrate how the sun, moon, and earth move.*)

15. Reconstruction through imagination. (*Write a diary of a trip from Washington to New York in 1775.*)

16. Stating examples for the purpose of illustration. (*State an experience of your own to illustrate a chemical change.*)

17. Classifying. (*What kind of a simple machine is used in the following devices: windlass, oar, etc.?*)

18. Illustrating facts graphically. (a) Graphs. (*Make a graph to show the relationship between the season of the year and the amount of water needed.*)

b) Maps. (*Make a map to show the paths of "highs" and "lows."*)

c) Diagrams. (*Make a diagram of the ventilating system of the school.*)

d) Plans. (*Draw a plan to show how crops are rotated on a farm that has four fields of equal size.*)

e) Cartoons. (Draw a cartoon to show the pull of gravity.)

19. Analyzing and using graphic material. (a) Graphs. (*Given a temperature graph, when was the temperature the highest?*)

b) Maps. (*What does the map show regarding the amount of rainfall in Kansas?*)

c) Diagrams. (*Describe the apparatus shown in the figure.*)

d) Tables. (*What conclusions can you draw from the facts given in this table?*)

e) Photographs. (*How does the picture show that either the earth or the stars move?*)

20. Obtaining data from original sources. (*Find out from a manufacturer how artificial ice is made.*)

21. Taking field trips. (*Study your own neighborhood to find out what measures are taken to keep it clean.*)

Increased skill in determining types of learning activities and their uses can be obtained by classifying the Self-Testing Exercises and Problems to Solve under the types given.

8. METHODS OF USING THE EXERCISES IN SMALL AND LARGE CLASSES. The method of using the exercises will vary in accordance with the teacher's decision to use the group or the individual method of instruction or a combination of these two plans. Whatever plan is used, there arises the question of available time to mark the papers. A few suggestions for handling this important phase of the technique are therefore in order. Since the amount of time available for this purpose is largely a matter of the size of classes, the suggestions are given in two groups, one for small classes and one for large classes.

a) *Small Classes.* Before they attempt the exercises, pupils should be instructed to read through the problem for a bird's-eye view of it, and then to make a second slower reading for details. If the problem contains experiments, the pupil should perform these as he reaches them. Since pupils progress at different rates of speed, only a few sets of apparatus will be found necessary. When the exercises on a given problem are completed, the paper is handed to the teacher and is graded immediately. Thus it is not necessary for many papers to be graded after school, and, furthermore, the teacher may confer with the pupil about the paper at the psychological moment. In cases where any point is causing confusion to the class as a whole, the teacher may find it advisable to clarify the point by a brief exposition or explanation.

If the exercises are not completed satisfactorily, the papers are immediately returned to the pupil. With beginning pupils it is worth-while to indicate in the margin the type of error. In general, the faulty answers may be classified as incomplete, incorrect, too broad, or off the question. Abbreviations of these words can be used in the margin to indicate each error. The pupil then corrects his paper and returns it to the teacher as many times as is necessary for him to do the exercises correctly.

If a record is kept of the number of attempts and the types of errors made by each pupil, it can be used as a basis of conference with the pupil. Every teacher knows that exhortations on methods of study and general directions for study have little value. Pupils will change their methods of study only when they have concrete evidence that their own method will not produce results, and when the teacher can demonstrate that another method is better. The records furnish this concrete evidence and lay the foundations for selling a better method to the pupil. For this reason the procedure followed is: first, give the pupil something to do; second, show him his error, if any, and try to indicate the fault in procedure which caused the error; and third, have him repeat the exercise or give him other exercises of a similar nature.

An excellent record form for pupil progress is illustrated on page 45. This record form is mimeographed and a copy is given to each pupil. The record indicates the final date of acceptance of the activity, the number of trials or attempts required to complete the activity in a satisfactory manner, and the types of errors made. The instructor initials the last column when the activity is accepted. At the end of the unit the instructor collects these records and enters the results in a master chart as shown in Table 4 and Table 5. The time of the teacher may be saved by passing the master chart to the pupils and having them enter their results on the chart.

A typical time record of completed exercises for one of the units is shown in Table 4, page 46. Several types of pupils are shown. The table is read as follows: Pupil A completed Exercise 1 correctly on the second day, Exercise 2 on the third day, Exercise 3 on the fifth day, and so on. Pupil A also worked on the Additional Exercises on the 14th, 15th, 16th, and 17th days. Pupils A and R are consistent, average workers. Very little attention from the teacher is necessary. Pupil B either loafed at the beginning of the unit or had considerable difficulty with Exercise 1. On the evidence of the record, K looks like a loafer or a very slow learner. The fact that he worked well toward the

RECORD OF PUPIL PROGRESS ON UNIT   HOUR........

SCIENCE COURSE.................... NAME....... ....

UNIT NO......... TITLE.......................................

INSTRUCTIONS. This sheet is to be a complete record of your work in the unit. List the written assignments of the unit in their order and attach your papers to this sheet each time you submit them, giving the date in the proper column the first time you submit a paper.

The mark on the paper at each attempt and the date of approval will be indicated by the instructor. Key to marks for errors: C—Content, M—Mathematics, F—General Form, ?—Doubtful meaning, X—English or other usage errors, I—Incomplete.

	TYPE OF ASSIGNMENT	DATE	MARK ON PAPER					INSTRUCTOR'S MARK
			1	2	3	4	5	
1	*Pre-test*	*9/2*						*9/2JCM*
2	*Presentation Test*	*9/3*	*X*	*OK*				*9/4JCM*
3	*Self-Testing Exercise 1*	*9/8*	*OK*					*9/8JCM*
4	*Self-Testing Exercise 2*	*9/10*	*I*	*I*	*OK*			*9/14JCM*
5	*Etc.*							
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

TABLE 4. TIME RECORD OF COMPLETED EXERCISES

Pupils	1st day	2d day	3d day	4th day	5th day	6th day	7th day	8th day	9th day	10th day	11th day	12th day	13th day	14th day	15th day	16th day	17th day
A		1	2		3		4	5	6		7	8	9–10	AE*	AE	AE	AE
B							1	2	3		4	5	6–7	8	9		10
F	1	2		3		4	5	6	7	8	9	10	AE	AE	AE	AE	AE
K		1		2			3			4	5	6	7	8	9	10	
Mc	1	2	3	4	5	6	7	8–9	10								
R		1	2	3	4	5	6	Absent	Absent	7		8		9	10		

* AE. Additional Exercises.

last part of the unit when everyone else was finishing would indicate that he can work under pressure. Pupil F is a rapid, consistent worker, doing more than the average of the class (the required number of exercises was 10; Pupil F did five Additional Exercises). Pupil Mc is an extremely rapid worker. She completed the required exercises very quickly and spent the remainder of the time on a supplementary project. An examination of the number of attempts required will help interpret the results of Table 4.

The record of the number of attempts required is shown in Table 5. Each time a pupil hands in an exercise, he is credited with one attempt on it. Under the system followed it is necessary that he complete it correctly. The number of attempts therefore measures his efficiency of work. The table reads as follows: Pupil A completed Exercise 1 correctly on the first attempt. Pupil B required four attempts on Exercise 1. It will be noted that Pupil B really did have trouble on Exercise 1. The large number of attempts required classifies him as a slow learner rather than as a loafer. Pupil K is now readily identified as a loafer. His small number of attempts shows that he could not have been working during all of the time he required to

TABLE 5. NUMBER OF ATTEMPTS REQUIRED

Pupils	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Total
A	1	1	1	1	1	2	1	1	2	1	12
B	4	1	2	3	2	1	2	1	2	1	19
F	2	1	1	2	1	1	1	1	1	2	13
K	1	2	1	1	1	1	2	1	1	1	12
Mc	2	1	1	4	2	1	2	1	1	2	17
R	2	1	1	1	2	1	2	6	2	1	19

finish the unit. This conclusion, however, should be followed by observation of the pupil, because it is possible that he might be an extremely slow, conscientious worker. If he is identified as a loafer, he may be shown these charts and be asked to account for his slowness. The teacher can then show him that it is due primarily to his dilatory habits. Pupils A and F need very little attention. Pupil Mc is working too fast. She would do better to slow down and thereby decrease the number of attempts necessary. She is sacrificing accuracy for speed. Pupil R and Pupil B need more careful diagnosis and attention, as suggested by the large number of attempts necessary.

Pupils may be kept informed of how their rate of progress compares with that of others by keeping a chart record of the progress of different members of the class and posting the chart in the classroom. However, there lies in such practice the danger of encouraging hurried and careless work.

b) *Large Classes.* Where classes are so large and where the study and teaching facilities are such that individual supervision of the pupils at work is impracticable, the teacher should plan to use the exercises in such a way that they serve as well as possible the purpose for which they are intended without overburdening himself with papers to be corrected. The doing of all of the Self-Testing Exercises, or of equally valuable exercises prepared by the teacher, is quite essential to the proper study of the text. Without such activities the work is likely to fall back to the unprogressive assignment-recitation form of instruction. In accordance with the purposes of the exercises, the following flexible plans for using the exercises in large classes and under conditions unfavorable to the best teaching are suggested for the teacher's assistance in making the study of the pupil effective:

1) Have pupils write reports on all exercises. Require certain ones to be handed in for your inspection. The pupil should not know beforehand which exercises will be called for, thus insuring that he does his best on every one. Nor is it necessary to have every pupil submit the same exercises. By such plan the teacher will have a check on the work of each pupil and not

overburden himself with papers to be corrected. Exercises not called for may be taken up in class discussion, pupils being asked to read their reports for criticism by the class.

2) Pupils may be asked to hand in certain exercises and to make brief notes on the points which they would include in reports on those not collected. The latter may then be considered in class discussion.

3) Pupils may be asked to write an answer to each of the sub-problems raised and to the major problems. The teacher can then first read the answer to the major problem. If this is correct, it is not necessary to read the answers to the sub-problems. If the answer is incorrect, the error will usually be found among the answers to the sub-problems. In case such an error is found, the teacher may direct the pupil to solve the sub-problem again and then to solve the major problem again.

4) Where the technique is entirely of the group instruction plan, pupils may be asked to make notes for their reports on each exercise in the text or to write their reports and be ready to report in class discussion of the problem. This is probably the least desirable of the plans suggested, for it does not, per se, insure individual thinking and activity, and does not lend itself so well to directed or supervised work.

5) If the group method of instruction is carried on, it is essential that it be adapted to the spirit of the book, which is inductive. First, a problem is raised; this is in turn broken up into smaller problems, each of which is solved by the presentation of certain data or by experiment, and the results of all are combined into an answer to the problem. As a rule this final combination organization must be done by the pupil in answer to the exercise.

A good method of group instruction is therefore to raise the problem with the pupils and get it firmly in mind by requiring several restatements of it by the pupils. Then have the class read through to the first experiment. This experiment may then be performed by the teacher in demonstration, or it may be performed by the pupils working in groups, or by the individual pupils, or by some one pupil. It is important in this connection

to let the pupils draw their own conclusions. Then turn back to the reading of the problem until another experiment is reached, and go through the same process.

When all of the experiments have been performed and the class has finished reading through the problem for the first time, set them doing the exercises. This in most cases will require further study of the problem. In order to be sure that each pupil does his own work, it is essential that these exercises be done in class if possible. Some of the brighter or faster pupils will probably finish before the rest of the class, and these may be supplied with additional exercises or supplementary projects until the group is ready to go on. Before beginning the next problem, it may be advisable to have a class discussion of the previous problem to insure that all have obtained an understanding. Any pupil who has done his exercises incorrectly can then correct them.

A plan such as outlined breaks the period into several parts: study, experimentation, and discussion.

ORGANIZATION

When the students have given satisfactory evidence (in assimilation tests) that they thoroughly understand a unit, that they really know the essential facts and relationships, they should proceed to the next step in the learning process—organization. Without books, notes, or other helps, each pupil is required to represent in some way the relative importance of the ideas in the unit and their interrelationships. The organization may take the form of (*a*) a list of the main ideas in statement form, (*b*) a statement or topical outline of the unit, (*c*) a diagram of the unit (see the graph for each unit).

There is a marked tendency for the pupil to include a large amount of assimilative material in the organization. This is particularly true if the outline is made too detailed. At first, it is probably best to have pupils make only the main points. As they attain skill in this process, they may be allowed to make their outline in more detail.

The organization, if properly used, provides a strong stimulus for thought about the facts and relations of the unit. It is not

to be regarded as a test, but as a step in the learning process. However, in so far as it is a thinking exercise and not an outline of the memorized text discussion, it is a quite reliable index of the pupil's ability to organize facts in a conscious and independent way. More than any other assignment of a unit, it stimulates growth in thinking power. (For detailed suggestions see the "Looking Back" sections and the unit graphs in this manual.) Motion pictures are often very helpful in showing pupils the unit in perspective and assisting them in picking out essential elements.

RECITATION

Following the completion of the organization by all the pupils, one or two periods may be given to oral or written recitation. The selection of recitation topics and the procedure in the recitation may follow several different plans, depending somewhat on the type of unit. In many cases the topics should be such that they will call for a re-presentation of the entire unit under a new organization. In other units a presentation of some part of the unit is advisable. Under any plan used, the student is expected to present his talk in a clear, well-organized, straightforward fashion, and in good English. He should assume that he is speaking to an audience made up of those who have not studied the unit. Any member of the class or the instructor may call upon the student to elucidate any point in his talk. Following the oral recitations those pupils who have not given satisfactory recitations and those who have not had an opportunity to speak may be required to write on a topic selected by the instructor.

In order to add interest to the recitation, the instructor may suggest to the pupils that they incorporate in their talk any additional material obtained from their reading or from talking the topic over with their parents. Pupils interested in some one phase of the unit may have done additional work on this phase. They can also be given opportunity to present the results of their investigation. The instructor may also suggest topics not directly based on the problems of the unit but re-

quiring that both speakers and listeners use their new understandings.

It is commonly the practice where the group plan of instruction is used to have a series of recitations on small blocks of the subject matter from day to day. It is highly advisable, however, to carry on the recitation for the whole unit as outlined above. This will furnish a review and will also insure that the unit is seen in its entirety rather than as a series of apparently unrelated facts and principles.

Correlation with Other Subjects

The written work in science affords the opportunity for correlation with the English department. The preview and the written recitation, both in narrative form, give excellent training in English composition. After the paper has been corrected for science, it may be turned over to the English teacher for further correction or elaboration. The organization, which is usually written in outline form as a series of statements, will also give the English teacher concrete material upon which to work. This may also be sent to the English teacher for correction. Quite often the English department will arrange to give credit for the written work in science. Drawings of apparatus, machines, etc., can often be arranged for in connection with the manual-arts department. Concepts developed in most of the units have important social implications and give opportunity for making direct connection with topics usually included in social-studies courses.

Testing Results

Several methods of testing results have already been referred to, namely, the exercises, organization, and written recitation. If the individual plan of instruction is followed and the pupils are required to work on the exercises until they are correct, the number of attempts required is a good measure of efficiency. The number of days required to complete the exercises correctly is a good measure of their rate of work. For use in grading it is possible to give a passing grade for the correct completion of a given number of exercises and to base higher grades on the completion of a given number of additional ex-

ercises or supplementary projects. This will set up a definite standard of accomplishment for the class. The organization furnishes evidence on the extent to which the pupil has visualized the whole unit and upon his ability to grasp the interrelationships of the problems which make up the unit.

In addition to the above measures many teachers find it advisable to give a test on the entire unit. Such objective types as the true-false, the completion, and the best-answer can be used to good advantage in this connection. These tests have the advantage of being easily scored.

6. PRINCIPAL TYPES OF DIFFICULTIES ENCOUNTERED BY PUPILS

Real teaching does not stop with marking the exercises as correct or incorrect; it goes further and tries to diagnose the cause for the difficulty and to give corrective treatment. A list of difficulties, with diagnosis and corrective procedure, follows.

1. **Misunderstanding the text or exercise.** This is due in some cases to carelessness in reading the text or exercise and in others to attempting the exercise before having a complete understanding of the text. The most common types of errors are incomplete answers, incorrect answers, and off-the-question answers. These can frequently be corrected by having the pupil write the title of the exercise in his own words and show it to the instructor before he begins. Pupils who habitually misunderstand the exercises should be shown the value of the habit of restating the exercise in their own words.

2. **Failure to identify the type of work needed to secure the answer.** When confronted with a thought question, many pupils simply read the question over and then hunt through the text to find the answer. If they cannot find some direct connection between the thought of the question and some passage in the text, they give up and inform the teacher that the answer isn't there; others find a few phrases in the text which are similar to those used in the test and write them as an answer; others write everything they can find that has any bearing on the question. This results mainly in answers which are off the ques-

tion or too broad, with a sprinkling of incorrect and incomplete answers. Here again the pupils must be shown that their faulty answers are due to incorrect methods of procedure.

Corrective work, of course, varies with the type of test. In some cases the pupil has failed to strip the question of its setting, and thus cannot identify it with the correct principle or application. Corrective work consists in having the pupil (1) restate the exercise in his own words, (2) ask himself, "What do I have to know to answer this exercise?" and (3) ask himself, "How shall I go about getting the answer?" When a pupil has difficulties in determining his method of procedure, the teacher should show him the method to be used in that case, and then give him practice in problems of a similar nature.

3. FAILURE TO SEE RELATIONSHIPS BETWEEN EXPERIMENTS AND SUBJECT MATTER. *Science Problems* is inductive in character and proceeds from applications to principles. For example, the pump is first studied as a working device, and then experiments follow which present the principle of science involved in its operation. Many pupils become so interested in the manipulation of the apparatus that they lose sight of the purpose of the experiment. The experiment thus tends to become something apart from the problem. Since the text is inductive, each experiment contributes some one fact or principle necessary for complete understanding. Consequently a pupil who has not grasped the relationship between the experiment and the subject matter either gives up or frames some totally inadequate answer.

Since not all of the problems are experimental, it is very easy to identify such a pupil. In correcting this error the teacher must prove to the pupil that his faulty answer was due to a failure to see the contribution of the experiment. If on the next problem which includes experiments he is required to write out the principles or facts presented by the experiments and then to do the test, the ease with which he can do the test gives him concrete evidence of the value of the method. Some teachers will prefer to have pupils write a report on each experiment.

4. TENDENCY TO MEMORIZE THE TEXT RATHER THAN TO RATIONALIZE IT. Pupils who memorize rather than rationalize

can be identified by observation. They read the text over and over, frequently turning their eyes away from the book and gazing off into space. Many of them move their lips as they say over and over the words of the text. The results of memorizing the text are also apparent in the test results, which frequently contain a word-for-word reproduction. This practice is soon broken up if the tests are so constructed that they call for reflective thinking with the memory element in the background.

5. TENDENCY TO FORM CONCLUSIONS WITHOUT WEIGHING THE EVIDENCE. The tendency to form hasty conclusions appears quite frequently and results in incorrect answers. Such pupils generally have a large number of attempts on exercises. If the record of attempts is kept by days, these pupils can be readily identified by the large number of attempts on any given day. This type of pupil is usually very fertile in suggestions, but he does not evaluate these suggestions sufficiently before formulating his response.

The habit which must be broken is that of taking the first suggestion which comes to mind. The habit to be inculcated is that of recalling or formulating as many solutions as possible, and then testing each solution in the light of its applicability to the problem at hand. The tendency also results in incomplete answers. In a question which involves putting together several ideas contained in different paragraphs, some pupils obtain a partial answer in one paragraph and then fail to combine with it equally important ideas in other paragraphs. This may be caused by the fact that the pupil has not studied the problem as a whole and has failed to grasp the organization.

6. INABILITY TO DISTINGUISH BETWEEN MAJOR AND MINOR POINTS. The inability to select essentials crops out most frequently in making outlines and summaries. In many cases it is caused by lack of knowledge concerning chapter and paragraph structure, in others to a lack of definite purpose on the part of the pupil in his selection of facts. Here the pupil should be taught the significance of the problem and sub-problem titles in guiding him in the selection of his facts and the use of signpost and summary paragraphs and topic sentences.

7. FAILURE TO USE OR INTERPRET DIAGRAMS, TABLES, ILLUSTRATIONS, AND CROSS-SECTION DRAWINGS. Many pupils regard illustrations as something to be looked at and then passed over. As a result of this habit many pupils do not know how to study illustrations or read diagrams, tables, graphs, and section drawings. This is particularly true of section drawings. In order to assist pupils in the interpretation of such drawings it is sometimes necessary to have both an illustration and a section drawing of the same device. Practice can also be given in making section drawings from the actual apparatus.

8. INABILITY TO TRANSLATE THE PRINTED WORD INTO A THOUGHT-PICTURE. An example of inability to translate words into thought-pictures is found in describing the operation of a pump. Many pupils memorize the steps in the operation without actually seeing the significance of each step. One way to identify such pupils is to have them draw the pump in different stages of its operation. For example, suppose that the section drawing in the text shows the piston and the position of the valves at the beginning of the first upstroke, and the rest of the operation is explained in the text. If the pupil is asked to show the position of the valves and the piston on the first downstroke and the second upstroke, giving reasons for the different positions of the valves and the rise of the water through the cylinder, he will be forced to rationalize the process. Many pupils can tell glibly how the pump operates without having the slightest understanding of its operation.

9. SUMMARY. The results obtained in following the procedure outlined are evidenced in three ways: the reduction of the number of attempts required to do the test exercises, the reduction in the number of errors, and the reduction in time required to complete the units.

The supervision of study in beginning courses of science consists in setting up definite tests, the results of which are used not only to determine the extent of the pupil's understanding but also to find out the incorrect methods of procedure which are responsible for faulty answers. The results also furnish the basis for teaching pupils how to study.

PART TWO

Specific Suggestions for Class Work on the Units

INTRODUCTION TO THE COURSE

It is suggested that at the first class meeting, teachers hold an informal discussion based on part of the Introductory section, "How are you changing?" pages iii-vi. Have the pupils read the first two paragraphs on page iii and then give their own answers to the question, "How has the study of science changed you?" before reading the answers given in the text. If there are pupils in the class who have not yet studied science, they may enter into the discussion by describing an experience in which observation of some event helped to change their previous ideas.

This discussion should not only make the pupils realize how the study of science has been of value to them but should help clarify the purpose of continuing the study in *Book 3*. Have the pupils read pages iv-vi in which some of the reasons are mentioned. The class should survey the table of contents, pages vii-x, to obtain a general picture of what they are to study.

In discussing this introductory material, especially pages iv and v, an excellent opportunity is given for enlarging on the broad social aspects of the use of science. What have been the effects of the new discoveries that man has made with the help of science? The development of a type of wheat that could grow in cold northern climates and mature during a short summer has made it possible for men to farm in parts of the world that had been considered useless for agriculture. Application of scientific methods of farming makes it possible for large populations to live where only a comparatively few people could be supported with old-fashioned methods of farming. Many more examples can be found to elaborate this idea. At the same time it should be pointed out that the results of scientific study are often misused, and that both the scientist and the people as a whole have a responsibility in directing the uses of science for the benefit of society.

Teachers should previously have read Section 5, Part One, pages 28-53, of their *Guidebooks* to be thoroughly familiar with the nature and function of the learning activities and the unit organization. For students not familiar with the *Science Problems* series the teacher may give the pupils orally the gist of this statement of the organization and study techniques of the book.

UNIT 1

How Do Living Things Behave?

FUNCTION AND SCOPE OF UNIT 1. A mere reading of the material in this unit will make it clear that the treatment is quite elementary, as befits the social and mental maturity of the pupil at this level. It should, therefore, not be difficult to present the material in such a way as to fulfill the authors' purposes in including such a unit and in making it the opening unit of the book.

Through the study of this unit the pupil should arrive at a better understanding of his own personality and reactions through realization that his mind and his emotions are not wholly mysterious but can be, to some extent at least, trained and controlled.

At every opportunity the pupil should apply the ideas and concepts, here presented, to himself in understanding and directing his own behavior and to others in understanding their actions.

Secondly, the study of this unit should bring to the pupil the realization that behavior is one of the basic properties of all living things. The pupil himself is used as a starting point since he furnishes the most obvious and probably the most interesting illustrations of behavior in living things. Subsequent examples of behavior in other animals and plants show how and to what degree behavior is a property common to all living things.

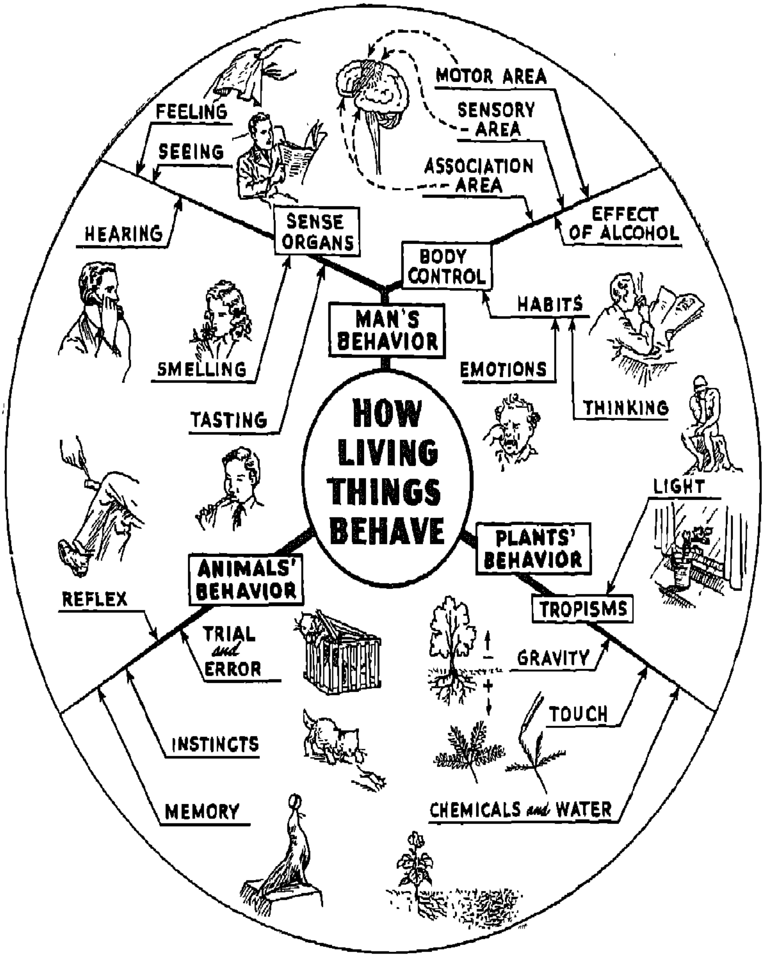


FIG. 1. GRAPH OF THE SUBJECT MATTER OF UNIT 1

Since this fundamental idea is of great importance in the study of living things, this unit is made the first of three biological units and forms a background for later biological units of the book. However, the purpose of Unit 1 is rather to acquaint the pupils with the factors of his own behavior and establish a feeling for the relation of man to other living things than to present ideas and terms needed in later units. Thus this unit is almost entirely independent of all other units in the book.

INTRODUCTORY EXERCISES (P. 2). 1. "Behave" is word in common use. Ordinarily it means to be good. This is not scientific meaning of term as it is developed on page 5. This idea should be brought out in discussion of page 5.

2. Responses will vary. Word "think" is not well understood by pupils. Answers can be used as part of discussion in section "How do we think?" pages 25-29.

3. Habits will include walking, reading, singing, skating, riding a bicycle, etc. Real value of habit lies in freeing upper centers of brain from necessity of directing act. Habit may be harmful if it has bad effects upon individual, for example, smoking, drinking, etc.

4. Responses will vary. Any animal that pupils commonly see can learn to some extent. Pupils with pets are likely to endow them with abilities that they do not have. If these are listed, evaluate them later in Problem 2.

*5. Ears, nose, eyes, tongue, organs of touch in skin, temperature, and pain. Pupils will probably know first five mentioned.

*6. Stimulus is agent that brings about response in living thing. Light, heat, and electricity are examples of such stimuli. All living things respond to stimuli.

7. Movement of leaves of plant when placed in window, turning of stem to grow upward, and of roots to grow downward may be given as examples.

8. Most scientists have come to the conclusion that animals such as dogs and horses cannot carry on reflective thinking. If examples given by pupils are analyzed, it will be seen that they can be explained by trial-and-error learning or by association.

9. Answers will vary.

*10. His brain permits him to reason, and his nimble fingers permit him to make a great variety of movements.

LOOKING AHEAD TO UNIT 1 (P. 3). Techniques for presenting the introductory material of the units of *Science Problems, Book 3* are given on pages 29-32 of this *Guidebook*. The teacher should refer to these pages and select the method which seems most profitable for the material of this unit and for his particular group of students.

The examples given in this section are for the purpose of showing pupils the two kinds of problems that arise in every type of behavior: (1) What the situation is to which the organism is responding and (2) what the organism does in response to the situation. They also show that the kind of behavior is related to the structure of the animal. One method of presentation is to make three parallel columns on the board. Write "Kind of Animal" at the head of the first column, "Kind of Stimulus" at head of second column, and "Kind of Behavior" at the head of the third column. Discuss the examples in the book with the pupils, secure other examples from the class, and enter results in the three columns.

PROBLEM 1: HOW DO HUMAN BEINGS BEHAVE? (P. 8)

The major function of this problem is to help pupils understand themselves. The examples of behavior used to develop the ideas are chosen from common experiences of the pupils. Pupils should be encouraged throughout this problem to tell of their experiences, and the class and the teacher should try to explain them. If possible, get pupils to see you privately to discuss problems that are personal in nature, particularly problems that arise with the incidence of adolescence. The main ideas to be developed during the study of this problem are:

1. The body is informed by sense organs of what is happening in it, on it, and at a distance from it.
2. Messages from the sense organs are made meaningful in the brain.
3. A situation or an event or an object is explained or made meaningful to you by those past experiences that you can recall.

3. Be sure you really want to form new habit. Start with determination and attention. Never act contrary to new habit until it is well formed.

4. Answers will vary.

PROBLEMS TO SOLVE (P. 24). 1. It is done as a habit built up through twelve months of repetition.

2. Other things being equal, the two are probably equally difficult. However, many habits that we call bad are in line with natural tendencies and may thus have been easier to form than good ones.

3. Answers will vary.

SELF-TESTING EXERCISES (P. 29). 1. Dog solves problem by trial and error. He tries this and then that until something works. Human beings can think ahead, plan what to do, and then do it.

2. Ape saw relation between length of stick and distance to object. This is simple thinking, such as we often do.

3. Thinking is process in which you see clearly nature of problem, consider various suggestions for solving it, and then pick out most likely method.

4. Answers will vary. May include deciding what dress to wear, studying, deciding what to do after school, etc.

PROBLEMS TO SOLVE (P. 29). 1. Answers will vary. Science and mathematics probably require most thinking. Pupil is required to generalize, explain, and apply principles.

2. List factors you must consider, such as time, cost, distance, purpose, etc. List advantages and disadvantages of each place and evaluate each. This would require thinking.

3. If words are merely associated, no thinking is required.

4. Adding column of figures is done by recalling number combinations. Arithmetic problem may require analysis to determine what is given, what must be found, how to proceed, etc. The latter requires thinking, while addition does not.

5. Answers will vary.

SELF-TESTING EXERCISES (P. 35). 1. Behavior ruled by reason is based upon deliberate thinking and is likely to be intelligent and sound, while behavior based on emotions is likely to be non-intelligent.

2. Answers will vary.

PROBLEMS TO SOLVE (P. 35). 1-2. Answers will vary.

3. Rate of breathing and rate of heart beat are increased; skin flushes; under exceptionally strong emotions strength is multiplied.

4. In general, no, although it is probably a good thing to be prejudiced against harmful things.

5. No. Person may be afraid of dog or thunder sometimes and not at other times. It depends to considerable extent upon physical condition and total situation at time of event.

SELF-TESTING EXERCISES (P. 37). 1. Reaction time determines how quickly person can act in emergency and avoid accident.

2. Slows reaction time, weakens judgment and self-restraint.

PROBLEMS TO SOLVE (P. 37). 1. Answers will vary. May include operating automobile or any kind of machinery, playing games that involve physical skill, getting out of way in times of danger, etc.

2. Answers will vary.

3. Any game of skill requiring muscular coördination, such as tennis, basketball, football, etc.

4. Most physicians consider alcohol useful as drug in certain situations.

5. Pupils may be sent to safety publications or asked to interview traffic officials.

PROBLEM 2: HOW DO ANIMALS BEHAVE? (P. 38)

This problem presents the various types of responses made by animals and shows how the behavior of any animal is related to the level of response of which the animal is capable. The various types of responses are also discussed in relation to human beings. It should be emphasized that in many ways man responds in the same way as other animals but that he possesses a greater ability to learn because of the greater complexity of his nervous system. The important ideas of this problem are as follows:

1. Trial-and-error behavior takes place when an animal makes various kinds of responses until a successful response results.
2. When a trial-and-error situation is repeated, an organism

learns by gradually eliminating the trial movements that bring no result.

3. A reflex act is an inherited type of response that is purely mechanical; a large part of the behavior of animals and of man can be explained by reflexes.

4. In conditioned reflexes old responses are connected to new stimuli; thus they are one kind of learning.

5. An instinctive act is inherited and consists of a chain of reflexes set off by appropriate stimuli in a general situation; instincts are usually of great value to animals. Very little of the behavior of man is controlled by true instincts.

6. The behavior of animals governed largely by reflexes and instincts is not intelligent.

7. Experiences may be recorded in the protoplasm and be recalled to govern some later experience; this is called memory and explains the behavior of many animals.

8. Human beings can analyze situations into many single events and remember them, and thus their experiences have greater meaning than those of animals.

SELF-TESTING EXERCISES (P. 44). 1. Behavior in which various responses are tried at random until one of them is successful.

2. Paramecium does not learn to distinguish successful from unsuccessful trials.

3. In thinking you plan mentally what to do. You consider many possible solutions and select solution that your judgment indicates to be most likely. In trial-and-error behavior you try the different methods as they come to mind without thinking of their probable success.

4. Cat through trial and error eliminated unsuccessful attempts and therefore learned to perform act. Experiment showed that cat eliminated useless movements gradually. Only after many trials was response learned. If cat had been capable of thought, it would have been able to open cage once secret of lock was discovered.

5. Examples will vary.

PROBLEMS TO SOLVE (P. 44). 1. Trial-and-error behavior. Afterwards it became habit.

2. You already have control of your muscles. Task is to get them to coördinate properly. Baby must first learn to control its muscles.

Self-Testing Exercises (p. 49). 1. Voluntary act results from willing act to take place. Involuntary act is not under control of mind.

2. Reflex act is inherited act which is set automatically into action whenever there is proper stimulus. Swallowing, dodging, breathing, rate of heart beat, coughing, sneezing, secretion of digestive juices, and regulation of body temperature are reflexes.

3. They relieve him from the necessity of willing acts to take place or directing their execution.

4. By connecting old response with new stimulus. This is done by presenting new stimulus at same time as stimulus that caused original response.

5. Reflex act is automatic and is specific response to specific stimulus. In trial-and-error behavior, stimulus is more general, and the responses may be varied.

Problems to Solve (p. 49). 1. Would have conditioned response. Finally he would react in same manner to either stimulus. He might avoid you and cower every time you spoke to him.

2. Would have conditioned response. He would associate slap with jumping on chair and would discontinue act.

3. Horses would become excited and would probably run after any passing fire apparatus. Response would be one of habit.

4. Pupil gets larger when eye is covered. When looking at near objects, pupil becomes smaller. This is type of reflex action.

Self-Testing Exercises (p. 54). 1. Inherited; chain of reflex acts, each act setting off next act; response to general situation; cannot be changed in lower animals but can be changed to some extent in higher animals.

2. Entire response can be analyzed into series of separate responses proceeding in regular order and not subject to modification. In response to egg-laying stimulus, wasp kills caterpillar, digs tunnel, stores caterpillar, lays eggs, and fills tunnel with dirt.

3. In general, instinctive acts help fit animal to its environment. They are ready-made responses that begin to function as soon as

animal comes into being. Thus certain acts essential to life maintenance do not have to be learned.

4. It cannot modify its responses to fit unfamiliar situations.
5. Individuals do many complicated things without having a chance to learn and have no idea what they are doing. Behavior is inherited response and is thus not learned by insects.

PROBLEMS TO SOLVE (P. 54). 1. Answers will vary but may include building nests, learning to fly, songs of birds, feigning death by some animals, assuming frightening postures, etc.

2. Insects are attracted by light and fly into flame.
3. Yes. It has all characteristics of instinctive response. (See answer to Self-Testing Exercise 1, page 54.)

SELF-TESTING EXERCISES (P. 59). 1. One event or act is connected in mind with another event or act.

3. Scientists marked bees with spot of paint when bees had discovered sugar water over yellow card. If bee with paint mark returned, scientists could observe to which dish it went.

PROBLEMS TO SOLVE (P. 59). 2-3. Sense of smell or hearing.

4. Association.
5. Method varies with kind of material to be memorized.

PROBLEM 3: HOW DO PLANTS BEHAVE? (P. 60)

The way plants grow and adjust themselves to their environment is largely explained by an understanding of the responses they make to different stimuli. If at all possible, the pupils should be stimulated to try experiments of their own on the reactions of plants, such as germinating seeds in different positions, turning seedlings over after germination has started, laying house plants in horizontal position in dark, etc. The main ideas of this problem are as follows:

1. Plants respond to gravity; the response is different in different parts of the plant.
2. Plants respond to light; different plants and different parts of the same plant respond in different ways.

3. The roots of plants respond to the presence of water and food materials in the soil.

4. Some plants respond to touch and to changes in temperature.

5. The responses of plants to stimuli are called tropisms; they are simple responses made by an organism without a nervous system.

a) A tropism is a turning toward or away from a stimulus; it is inherited and purely automatic.

b) Tropisms fit the plant to its environment.

Experiment 1. Can Gravity Change the Direction of Growth of the Stem and Root of a Plant? (p. 61). Materials and apparatus needed for the experiment are as follows:

Seeds (bean, clover, morning glory, mustard, or radish)
Small flower pot
Large flower pot
Knife
String to support flower pot
Rich soil

A supplementary experiment to show the effect of gravity may be carried out in this manner: Place a piece of blotting paper on a slightly larger piece of window pane or old glass photographic plate from which the film has been removed. Moisten the paper and plant radish or mustard seeds. Fit a strip of wood or heavy cardboard around the blotter, cover the seeds with another piece of glass, and bind the edges together with tape. Keep the blotting paper moist. Turning the glass at various angles from time to time will make an odd and interesting-looking plant.

Experiment 2. How Do Food Materials and Water in the Soil Act As Stimuli to Roots? (p. 62). Materials and apparatus needed for this experiment are as follows:

Box
Large flower pot
Cardboard
Rich soil
Sand
Bean or pea seeds
Rubber or cork stopper
Sealing wax

a) When the water is added, some of the materials in the rich soil will spread toward the sand; thus there will be materials in the sand from the rich soil. The roots will respond by growing toward the place of greater concentration.

b) The roots of the plant will all grow toward the center, showing a response to water. Have pupils look down at the box from above and make a drawing showing the pot in the center of the box.

EXPERIMENT 3. HOW DO GREEN PLANTS RESPOND TO LIGHT? (P. 63). Materials and apparatus needed are as follows:

Flower pot or pan
Tight box with hole, 2 in. diam., in one side
Radish seeds
Young sunflower or sweet clover plant

a) No difficulty will be experienced with this part of the experiment. Have the pupils make a drawing showing the bending of the stems toward the light.

b) An interesting drawing may be made of the various stages in the response of the leaves to light.

c) Other members of the composite family, such as rosinweeds, Spanish needles, asters, chrysanthemums, and dahlias; and of the pulse family, such as beans, peas, and peanuts, may also be used.

EXPERIMENT 4. HOW DO SENSITIVE PLANTS RESPOND? (P. 65). Material needed: sensitive plant (*Mimosa pudica*).

When the leaf is touched lightly, it folds up slightly. When it is pinched, it folds up quickly; and the petiole drops down parallel with the stem of the plant. After a time the leaf regains normal position. The leaf will respond a second time, but not so vigorously as the first time, if the experiment is repeated at too frequent intervals.

SELF-TESTING EXERCISES (P. 68). 1. Light, gravity, moisture, chemicals, touch, temperature.

2. Inherited automatic response resulting in turning movement

toward or away from stimulus. Usually applied to organisms having no nervous systems.

3. Turning movement toward favorable stimuli and away from unfavorable stimuli keeps roots and stems growing in direction which makes for best growth.

PROBLEMS TO SOLVE (P. 68). 1. Roots grow down and stems grow up regardless of position of seed. Roots of plants grow toward areas richest in food and water. Roots may grow into tile pipes in response to water. Leaves of plants turn toward light. Some flowers respond to light; some to changes in temperature. Some plants have sleep movements. Some plants respond to touch. Venus's-flytrap catches and digests insects. Leaves of trees drop in fall, thus preventing evaporation.

2. Turn plants in window around to keep them growing straight, plant climbing vines near support, waste no time putting seeds right-side up in ground, etc.

LOOKING BACK AT UNIT 1 (P. 69). 1. (*a*) C, (*b*) W, (*c*) C, (*d*) C, (*e*) W, (*f*) C, (*g*) W, (*h*) C, (*i*) C, (*j*) C, (*k*) C, (*l*) C.

2. Responses should include many if not all of the major ideas listed at beginning of each problem, pages 61, 65, and 68.

3. Pupil answers will of course vary widely in phrasing.

Association: connecting two events, ideas, or things.

Association area: part of brain which receives stimuli from sensory area and connects them with past experiences.

Avoiding reaction: type of behavior in which organism reverses direction of its movement.

Instinctive behavior: series of reflex acts resulting from general stimulus.

Involuntary action: action not under control of will.

Conditioned reflex: association of old response with new stimulus when old and new stimulus are received simultaneously.

Behavior: anything that living things do.

Cerebrum: upper part of brain where thinking takes place.

Habit: performance of a learned act without conscious control because it has been done that way many times.

Impulse: message sent along nerve.

Motor area: brain center that sends messages to muscles.

Reaction time: time necessary to respond to stimulus.

Reflex act: involuntary act; it is always particular response to particular stimulus.

Response: anything that animal does in reacting to stimulus.

Sensory area: part of brain that receives impulses from sense organs.

Thinking: process in which person evaluates suggestions that come to his mind and selects what seems to be best possible course of action.

Tropism: kind of inherited automatic turning toward or away from stimulus, occurring in organism without nerves.

ADDITIONAL EXERCISES (P. 70). For reference questions refer pupils to *Readings in Science,* pages 713-714 of the text.

2. Reflex action. Message travels from hand to reflex center and back to muscles without at first going to association area.

4. Walking movements are under control of lower centers of brain; therefore, person need not be conscious to walk.

5. As a rule, he will grasp pencil in palm of hand (palmar reflex).

7. It will learn.

11. If he learns, it will be by trial and error.

12. You have to learn to control the muscles of your arm and fingers to get proper coördination.

BULLETINS AND PAMPHLETS FOR UNIT 1

At the end of some units there is a list of bulletins and pamphlets that are available, either free or for a nominal sum. Most of these are publications of the United States government. Where prices are given, the bulletins may be obtained from the *Superintendent of Documents, United States Government Printing Office, Washington, D. C.* Where prices are not given, the bulletins may be obtained free by writing to the various departments, bureaus, or services at Washington, D. C., and specifying the exact title and number.

Great numbers of the publications of the United States government are of value to science teachers. Upon request the *Weekly Lists of Selected United States Government Publications* will be sent regularly. These describe many of the recent issues. A complete set of *Price Lists* of available publications may be obtained from the Superintendent of Documents.

Useful publications may also be secured free from the various state departments of agriculture and state universities and agricultural colleges.

Agricultural Technical Bulletin 270. *Chemotropic Responses of House Fly, Green-bottle Flies, and Black Blowfly.* 1931. 5c

Children's Bureau Publication 135. *Habit Clinics for Child Guidance.* 15c

Fisheries Bulletin 15. *Homing Instinct and Age at Maturity of Pink Salmon.* 5c

Public Health Reprint 1265. *Nature and Effect of High-frequency Electric Field upon Paramecium.* 5c

VISUAL MATERIALS FOR UNIT 1

As motion pictures, slides, filmstrips, photographs, charts, etc., contribute much toward making science instruction more meaningful to pupils, a few selections have been made for most of the units. In Part Four, Publications and Teaching Materials for the Science Teacher, there are lists of sources of these materials.

FILMSTRIPS

Society for Visual Education
  "Alcohol and the Nervous System"
  "The Effect of Alcohol on the Entire Man"

MOTION PICTURES

Encyclopaedia Britannica Films
  "Beavers"
  "Reactions in Plants and Animals"
  "Spiders"

Lehigh University, Bethlehem, Pa., Adelbert Ford, Dept. of Psychology. By mail order to this address. These films to be purchased.
  "Conditioned Responses"
  "Motor Aptitude"
  "Reaction Time"
  "Intelligence of White Rats"

Ohio State University, Columbus, Ohio., Dept. of Psychology. Psychological films for sale.

How Do Scientists Classify Living Things?

FUNCTION AND SCOPE OF UNIT 2. The title of this unit may raise a question in the teacher's mind as to whether it is an old fashioned study of taxonomy in a new setting. Thus a brief statement of the general objective of the unit is needed to help the teacher in his preparation for presenting this material. The main emphasis is upon *how* the classification is accomplished and upon the use which the well-educated person can make of the knowledge of relationships which exist among living things. Always, then, the use of scientific methods of approaching and solving problems must be kept before the pupils as the unit is developed. Likewise, ample opportunities must be provided for the pupils to apply what they learn about the relationships of living things to the plants and animals which are a part of their environment.

The academic viewpoint, classification for classification's sake, is to be avoided at all times because the mere mastery of dry facts is likely to result from such an outlook. One way of avoiding such a pitfall and of making the unit a vital, dynamic experience is to ask the pupils to bring to school for study any living things (or things which have been alive—sea shells, mounted insect specimens, etc.) that they have collected. Provide a large table or shelf in the classroom or laboratory for pupil-owned specimens and as the study progresses the pupils can group the specimens to show their relationships. This procedure is valuable from several standpoints and is almost certain to produce good results. First, it provides a beginning point based upon pupil experiences (collecting and caring for plants and animals), thus making the pupils feel that they have a vital part in the study instead of the feeling of teacher-imposed material. Second, the pupils are certain to provide new specimens as the unit develops, thus insuring new experiences and heightening interest. Also, the text material can in this way be

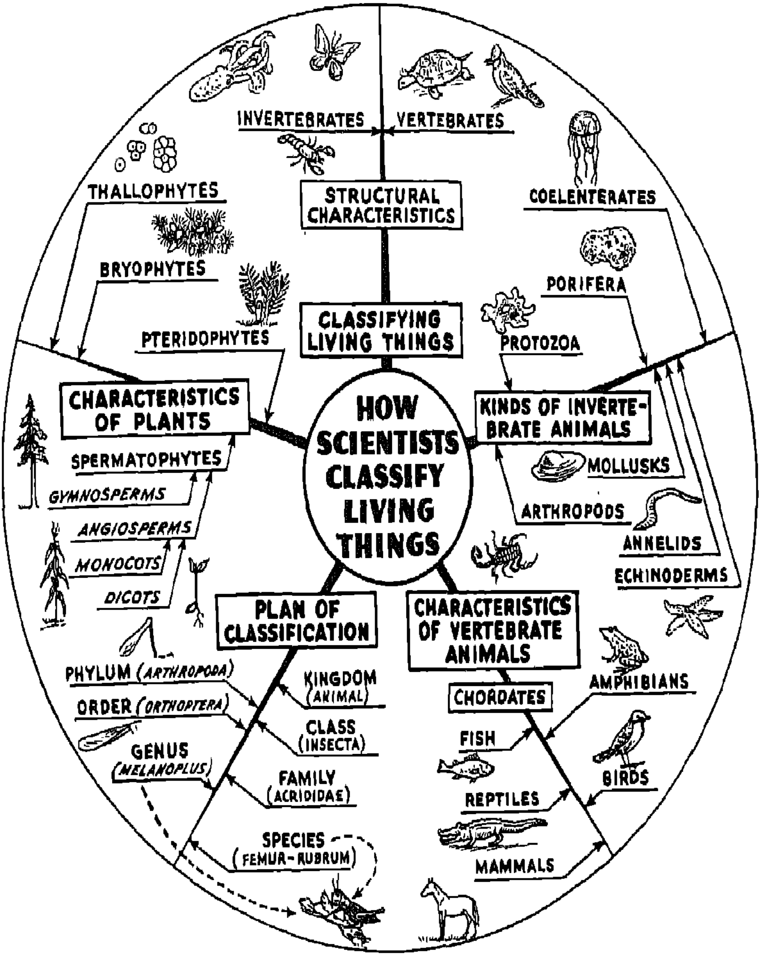


FIG. 2. GRAPH OF THE SUBJECT MATTER OF UNIT 2

supplemented with local material which will allow the unit to function as a study of the relationships of living things of the environment.

The grouping of the specimens worked out by the pupils will most probably be based upon a modification of some scheme which follows the outline suggested in the text. A specimen arrangement which is planned to show relationships is given here for illustrative purposes. It should be modified by the teacher and pupils (as they work together) to meet local conditions. The use of actual specimens can be as simple or as elaborate as is practicable, and the smaller classifications within various groups can be carried as far as time and the ability of the group permits.

A large table (or several tables together) could be covered with heavy wrapping paper and the specimens temporarily grouped into *plant* and *animal* divisions. As the study proceeds, the table could be marked off by the pupils in a manner similar to that shown in Table 6 and labels describing the characteristics of each group could be made and put in their places as the pupils learn the characteristics of the different groups. Specimens should be fitted into their proper places by considering their structural characteristics as described in the text. Relationships of a few specimens (see page 127 of the text) may be traced all of the way through to *species* to show how scientists actually work in classifying living things.

The study of this unit is related to earlier science experiences of this series, specifically, Units 8 and 11 of *Science Problems, Book 1,* and Unit 10 of *Science Problems, Book 2.* Also, this unit provides concepts which aid in a clearer understanding of Units 10 and 11 of this book.

An important supplementary exercise which should be fitted into the unit (where according to the teacher's judgment it can function best) is the use of simple keys in learning how to find the names of common plants and animals. For example, many state forestry departments publish simple books for identifying common forest trees of their states. Copies of these can usually

TABLE 6. PLAN FOR ARRANGING TABLE IN STUDYING HOW LIVING THINGS ARE CLASSIFIED

ANIMAL KINGDOM	Invertebrates	Arthropods	Crustacea
			Myriapoda
			Insecta
			Arachnida
		Mollusks	
		Segmented worms	
		Echinoderms	
		Coelenterates	
		Sponges	
		Protozoans	
	Vertebrates	Mammals	
		Birds	
		Reptiles	
		Amphibians	
		Fish	
PLANT KINGDOM	Seed plants	Angiosperms	Dicots
			Monocots
		Gymnosperms	
	Spore bearers	Pteridophytes	
		Bryophytes	
		Thallophytes	

be procured free by the teacher and used with the pupils in identifying a few trees in the community. It should be remembered in this exercise, as in the rest of the unit, that the emphasis should be placed upon *how* to use the key rather than upon memorizing the names of many different kinds of trees. This type of exercise affords ample opportunities for pupils to put into practice some of the principles which they have learned during their study of the unit, thereby serving as a method of evaluation of pupil experiences.

INTRODUCTORY EXERCISES (P. 72). *1. (*a*) All living things are made of cells. All living cells contain protoplasm which carries on all activities of cell. Cells are of different kinds and do different things for plant or animal body. Cells grouped together in organs in all but simplest plants and animals. (*b*) They are all largely made of protoplasm that does all things that living things do, such as take in food, grow, give out wastes, etc.

*2. Bacteria, protozoa (Ameba, malaria germ), one-celled algae (Pleurococcus), yeasts.

5. By certain characteristics or combinations of characteristics that no other bird or tree has. In the case of bird, size, color, song, shape, kind of bill, feet, etc. In the case of tree, size, shape of leaves, kind of bark, etc.

6. Keeps things in order; can talk about them because people understand us if they know characteristics of different groups; knowing characteristics of different groups will know something about thing if we know it belongs to certain group.

7. (a) Fish has gills and no lungs; lives in water. Snake has lungs and can live on land. Fish has fins; snake has no fins. *b*) Both have backbones; both have scales; both cold-blooded.

8. Size, shape, color.

LOOKING AHEAD TO UNIT 2 (P. 73). Two main ideas stand out in the consideration of this preliminary material and should be so thoroughly stressed that they are clearly understood: (1) In everyday life we put things into groups for convenience in using them—it is the natural thing to do. (2) Scientists put living things into groups to enable themselves and others to find out what living things are and to understand more clearly how they are related to each other. This latter idea introduces the system of scientific nomenclature.

Several procedures may be used in presenting this preliminary material. The pupils may bring specimens of living things to class, as suggested on pages 74 and 76. Questions are certain to arise as to the identity of some of the specimens and these questions may be used by the teacher to show the need of knowing how to find out what these specimens are. Class discussions of the specimens may be conducted along lines suggested by the material on pages 73-78 of the text, the pupils having read these pages previously, or they may be read in class to serve as guides for the discussions.

Another procedure is to use the text material plus the experiences of the pupils as the basis for class discussion to develop the main ideas that have been suggested and to lead into the problems of the unit. With either procedure, the story of Linnaeus and Artedi should be carefully developed to provide the beginnings of the understanding of the present system of scientific nomenclature and of the relation of different groups of living things to each other.

PROBLEM 1: WHAT DO SCIENTISTS DO WHEN THEY CLASSIFY LIVING THINGS? (P. 79)

This problem introduces the pupils to the main idea of the unit—that scientists put living things into groups (that is, name and classify them) by means of their plan of body structures. The teacher should be thoroughly acquainted with the plan of the problem to present it effectively. It deals with animals, most of which are already familiar to the pupils. The pupils are first asked to separate animals into large groups by means of rather obvious structural characteristics. The process continues with the animals being separated into smaller groups, until finally a single group (birds) is traced through until they are placed in the smallest possible group that can be chosen by using common names (White Leghorn, White Wyandotte, etc.) Much use should be made of the diagram on page 84 which can be outlined on the blackboard as the work proceeds. Much use should also be made of Figures 61, 62, 63, and 64.

No attempt is made to acquaint the pupils with the structural characteristics of *fish, amphibians, reptiles, birds,* and *mammals* at this point. Developing the structural characteristics of these groups in this problem would rob it of its overview value and probably confuse the pupils. The main ideas to be developed during the study of this problem are:

1. Different kinds of animals (and plants) have different plans of body structure.

2. (a) Invertebrate animals have no backbones.
b) Vertebrate animals are those which have backbones (other structural characteristics are not given here).
c) The important groups of vertebrate animals are *fish, amphibians, reptiles, mammals,* and *birds.*

3. Scientists use structural characteristics of animals (and plants) as the basis for classifying them.

SELF-TESTING EXERCISES (P. 85). 1. *Structure of animal.* Used because structure shows relationships between individuals and different groups and gives natural classification.

2. All vertebrates, i.e., all have backbones.

3. Have feathers.

4. Shows how animals are divided into smaller and smaller groups according to their structure. Smallest groups are most closely related.

PROBLEMS TO SOLVE (P. 86). 2. *Chinaware:* shape and use; kind of clay used; maker or place where made. *Automobiles:* style; maker; number of cylinders. *Dogs:* size; breed; use; color; length of hair.

3. (a) Helps keep things in order. (*b*) Can talk about things if have specific name for them and people will understand what we are talking about. (c) If we know characteristics of groups of things, we can identify new or unknown things.

PROBLEM 2: WHAT ARE THE KINDS OF ANIMALS THAT HAVE NO BACKBONES? (P. 86)

This problem provides opportunities for a fascinating survey of invertebrate animals beginning with the simplest, one-celled types and progressing to highly complex types (arthropods). A glance at the organization of this problem and the phyla which are included show that representatives of all phyla are not present. However, the most common and important groups are present. In case the pupils' interest leads them to bring in representatives of phyla not included in the text, the teacher should refer (or may refer the pupils) to any good zoölogy text. There the structural characteristics of the animals can be used for placing each animal in its proper phylum and this information can be added to the classification scheme that is being used.

As the teaching progresses, the teacher must be very careful not to overstress the characteristics of any single animal. One way of avoiding this is by asking questions similar to the following with the study of each phylum: How can you tell that clams, snails, oysters, squids, and octopuses all belong to the same group of animals? How are the animals of this group different from the segmented-worm group?

In other words, the stress is to be placed upon *similarity of structure of animals of a given phylum* and the relationship of one phylum to another is to be developed by a comparative study which points out *that each phylum has its own peculiar characteristics.*

In most localities it will be possible to secure some living representative of each phylum included in the text. It cannot be too strongly urged that living specimens should be used and that several different animals of each phylum should be secured whenever it is possible. Of course the specimens will vary for different localities, as is to be expected, and these specimens should be collected on field trips with the pupils who are allowed to care for the animals as they are studied and put into their proper groups according to the plan suggested on page 76 or some similar plan. In case no representative of a given phylum can be obtained locally (the Echinoderms in particular), biological supply houses provide either living or preserved material at reasonable costs.

Splendid individual or group projects may be developed by having the pupils collect and care for living specimens during the study. Specimens may be kept on feeding tables or other separate convenient places until they are moved to the "classification table" mentioned earlier. In cases where living specimens are not possible, preserved material will have to be used. This can either be secured from a supply house or preserved by the teacher at a time when the material is plentiful. The main ideas to be stressed in this problem are:

1. The simplest animals are Protozoa, or one-celled animals.
2. "Sponge animals" (Porifera) are distinguished from other invertebrate animals by possessing millions of tiny pores.
3. "Coelenterate animals" have central body cavities with one opening (the mouth), tentacles with stinging cells, and bodies that are built on a circular plan.
4. Echinoderms have spiny or leathery body coverings, water-vascular or circulatory systems, and their bodies are built on a circular plan.
5. Segmented worms (Annelids) are characterized (*a*) by having their bodies divided into segments all of which have nearly the same shape, (*b*) by having a complete system of blood tubes, (c), by having a tube-like digestive system, and (*d*) by having a well-developed nervous system.
6. Mollusks are distinguished from other invertebrate animals by means of soft bodies that are often covered with hard shells, their bodies are not divided into definite segments, and the appendages are jointed.
7. Arthropods are animals whose (*a*) bodies are usually divided into three parts, (*b*) legs and other appendages are jointed, and (c) bodies have a hard covering known as chitin.

EXPERIMENT 5. WHAT IS THE STRUCTURE OF THE AMEBA? (P. 87). The apparatus and materials needed are:

Leaves or grass from pond or damp place to start culture
Large glass jar or dish
Cover for dish (glass plate)
Medicine dropper
Compound microscope
Microscope slide, cover glass
Optional: prepared slide of Ameba to be used in case no specimens are found in culture

The directions in the text are sufficient for carrying out the experiment. Pupils who show a special interest may be encouraged to locate and draw as many different kinds of Protozoa as can be found. Some of these can be identified by the pupils with the help of reference books.

EXPERIMENT 6. WHAT IS THE STRUCTURE OF A PARAMECIUM? (P. 88). The apparatus and materials needed are:

Green "scum" from pond
Covered glass jar or dish
Medicine dropper
Compound microscope
Microscope slide, cover glass
Optional: prepared slide of Paramecium in case no specimens are found in culture

The most important factor in getting a fertile culture of paramecia is to cause rapid decay of plants which is accompanied by the growth of many bacteria. One of the best ways is to crowd a mass of algae or pond weed into a jar of water and place it in a dark place for a few days.

These tiny animals move so rapidly that they may be difficult to observe. Some of those caught among small bits of debris will be slowed down enough to be seen rather easily. Caution the pupils not to expect the parts of the animal to show up as plainly as they do in Figure 70 in the text. Note especially the complexity of the paramecium's body structure in comparison with that of the ameba.

SELF-TESTING EXERCISES (P. 91). 1. Both one-celled animals.
2. Consist of only one cell.
3. Different parts of the cell do different kinds of work.

4. (*a*) T; (*b*) T; (*c*) T; (*d*) T; (*e*) T; (*f*) T; (*g*) F.

5. Probably originally lived in small body of water or moist place that dried up. Protozoans dry up into tiny particles that blow about in air and drop on leaves and grass, etc., with dust. When grass is put into water, protozoans become active again.

6. Several protozoans cause serious diseases, such as amebic dysentery and malaria.

PROBLEMS TO SOLVE (P. 91). 1. Some of common soil and water forms: Euglena, Chilomonas, Peridinium, Ceratium, Volvox, Didinium, Stentor, Vorticella, Colpoda.

SELF-TESTING EXERCISES (P. 94). 1. Has millions of tiny pores.

2. (*a*) Water goes in through many tiny pores. (*b*) Walls of pores have tiny whip-like hairs that make current of water flow into pores and out through larger openings.

3. Cells take food from water that passes through sponge and digestion of food takes place in cells.

LEGEND UNDER FIGURE 84 (P. 99). Circular plan; tentacles around opening.

SELF-TESTING EXERCISES (P. 99). 1. (*a*) Built on circular plan. *b*) Has central cavity with only one opening; this cavity used as digestive cavity; has tentacles with stinging cells that kill and capture food for animals.

2. Has nervous system; digestion occurs in digestive cavity; built on circular plan; has tentacles with stinging cells; has no pores.

3. Have tentacles with stinging cells that paralyze larger animals. Have central cavity where larger animals can be digested and food in solution sent to cells.

4. Have nervous system.

PROBLEMS TO SOLVE (P. 100). 1. Some have no skeletons to support them; need water to bring food within their reach; have no waterproof coverings to keep them from drying out.

2. Jellyfishes, sea-anemones, sea whips, sea fans, etc.

SELF-TESTING EXERCISES (P. 105). 1. Have special digestive system inside body cavity; have water vascular system; have spiny or leathery skins; lack stinging cells.

2. Has several different systems each of which carries on certain work for the animal.

3. Spiny, leathery skin; circular plan with water-vascular system.

SELF-TESTING EXERCISES (P. 108). 1. Division of body into segments of nearly same shape.

2. (a) Soil passes through mouth into digestive tube as worm moves through soil. Digestible materials in soil are used by worm, and undigestible parts pass out through anus.
b) Burrow through earth and make holes. As they burrow, soil is taken into digestive systems and given out again. Soil is thus taken from one place and deposited in another, leaving hole where worm has been.

PROBLEMS TO SOLVE (P. 108). 1. (a) "Streamlined" body can work way through small holes in soil; (b) has sensory cells that respond to light, touch, etc.; (c) has central nervous system with brain that helps control actions in response to stimuli; (d) digestive system that can digest and eject soil; (e) must stay in ground or out of sun because of thin skin.

2. (a) Worms usually go under moist towel paper.
b) Worms usually go away from strong light toward faint light or dark place.
c) Worms usually try to crawl away from blunt object. When touched with a sharp object, they react by more violent movements or by threshing about. They may give out much slimy mucus.
d) Blood in upper vessel flows from back to front. Five large vessels (hearts) carry blood from upper large vessel to lower large vessel. In front of hearts, smaller vessels carry blood from upper vessel to body wall and back again.

SELF-TESTING EXERCISES (P. 112). 1. Have soft bodies; bodies not divided into definite parts or segments; appendages not jointed.

2. Clams, oysters, snails, octopus.

PROBLEMS TO SOLVE (P. 112). 1. Many used as food; shells used for making buttons; some shells used for jewelry (abalone); squids used for fish bait; pearls made by oysters are valuable jewels; contents of ink sac of cuttlefish makes sepia ink used by artists.

2. Small grain of sand or parasite gets in between shell and outer edge of soft body. Cells on edge indent and surround particle. Cells secrete thin concentric layers of pearly substance. Particle finally surrounded by pearly material.

SELF-TESTING EXERCISES (P. 114). 1. Have external skeleton; have jointed appendages.

2. Scorpion, beetle, grasshopper, crayfish, etc.

PROBLEMS TO SOLVE (P. 115). 1. Distinguishing characteristics of each invertebrate group clearly given in text.

2. Figure 105: (*a*) *Polychaet worm:* Annelida; body divided into segments of nearly same size. (*b*) *Nautilus:* Mollusca; hard shell formed around most of soft-bodied mollusks left when mollusk dies. (*c*) *Coral:* Coelenterata; circular, hard shell, branched and tree shaped. (*d*) *Click beetle:* Arthropoda; hard outer skeleton; jointed body and appendages. (*e*) *Euglena:* Protozoa; one-celled.

PROBLEM 3: WHAT ARE THE CHARACTERISTICS OF ANIMALS WITH BACKBONES? (P. 116)

This problem is similar in its organization and treatment to the preceding problem. It develops the characteristics of vertebrates in general, and then proceeds to separate these animals into smaller groups known as classes (fish, amphibians, reptiles, mammals, and birds). During the development of the problem the differences between vertebrates and invertebrates should be clearly shown. Then the structural basis for separating the vertebrates into their smaller groups can be studied. It should be stressed again that the emphasis should be upon *similarity of animals of each group* (fish, amphibians, etc.) and upon the peculiar characteristics which enable scientists to know which animals belong to specific groups.

Again, living specimens should be secured and cared for by the pupils. As these specimens are studied, they should be placed in their proper groups—fish or tadpoles may be kept in an aquarium, frogs and turtles in a terrarium, a small mammal in a suitable cage (white rats, guinea pigs, or suitable native animals), and a canary (or other tame bird such as a chicken). The list of animals in each group may be extended indefinitely according to the time available, facilities, and pupil interest and ability. The main ideas to be developed during the study of the problem are:

1. Vertebrates are animals that have backbones made up of vertebrae (in general), spinal, or nerve, cords (dorsal), well-developed body systems, and breathing organs connected with the front end of the food tube.

2. Fish are aquatic animals that breathe by means of gills (usually), have body coverings of scales, and are cold-blooded.

3. Amphibians are cold-blooded animals that spend the first part of their lives in water (breathing by means of gills) and later develop lungs; they are then able to come out of the water and live on land as adults.

4. Reptiles are cold-blooded animals that have body coverings of scales or bony plates and breathe by means of lungs.

5. Birds are warm-blooded animals that possess body coverings of feathers and breathe by means of lungs.

6. Mammals are warm-blooded animals that possess milk glands to feed their young, possess a partial or entire body covering of hair, and have the interior of their body cavities divided into two parts by means of diaphragms.

Self-Testing Exercises (p. 120). 1. Characteristics of different vertebrate groups clearly stated in text.

2. In adult stage amphibians have lungs and usually live on land with a very few exceptions. Fish never have lungs but breathe by means of gills and must always live in water.

3. Reptiles have scales or bony plates developed from skin; do not have gills at any stage of life but always have lungs.

4. Have feathers.

5. Have milk glands to feed young; have hair on all or part of body; have diaphragm dividing interior cavity of body into two parts.

Problems to Solve (p. 121). 1-6. These questions can all be answered by referring to such books as those listed for this unit in *Readings in Science*, pages 714-715 of the text, or to any good encyclopedia or zoölogy book.

PROBLEM 4: WHAT PLAN OF CLASSIFICATION DOES THE SCIENTIST USE? (P. 122)

The very heart of the unit is reached in this problem which is built upon the background provided by the preceding problems—that scientists' classification of animals depends upon the body structure of the animals. Detailed treatment of the steps actually used in classification is shown from the largest group (kingdom) to the smallest and final group (species or sometimes sub-species). Stress should be placed upon the fact that all along the line from the largest group to the classification into species there is a narrowing of structural characteristics which ultimately brings an animal into a final group by itself. For example, the grasshopper described on pages 126-127 of the text is related to all other arthropods because these animals all have jointed legs and other appendages, a hard exoskeleton, and three body divisions. But there the relationship stops, for each of the other classes of arthropods has some characteristics which terminate its relation to the class of the grasshopper (Insecta).

Crustaceans have more than three pairs of legs; myriapods have numerous body segments, and arachnids have four pairs of legs, no antennae, etc. However, the class Insecta has many smaller groups (orders) in which the relationship continues. Thus the relation of insects can be traced much further. The grasshoppers and the cockroaches have leathery and straight front wings and net-veined rear wings which places them both in the same order, Orthoptera. Here the relationship stops; the grasshopper having hind legs (and other characteristics) which are different from those of the cockroach. This places these insects in different families, but the relationship has continued for a long while; through *kingdom, phylum, class,* and *order.*

After order the relationship of these two animals stops, the grasshopper belonging to its own family (Acrididae), genus (Melanoplus), and species (Femur-rubrum). However, another kind of grasshopper mentioned on page 127 has a much closer relationship with the grasshopper that has just been classified than does the cockroach. This other grasshopper (Melanoplus spretus) belongs to the same *family* and genus, differing only in *species*. This makes these two kinds of grasshoppers about as closely related as any two animals not belonging to the same species can be. They differ only in slight details. Thus not only is classification based upon body structure, but relationships as well can be traced by this means; and the longer the relationship persists through the steps of classification, the more closely alike and more nearly related are the animals that are being considered.

As this problem is being studied by the pupils, *actual* specimens of each of the classes of Arthropoda should be examined so the pupils will have first-hand knowledge of how the separation into classes is made; since no substitute has yet been found for first-hand experiences. The same thing is true of the orders of insects; actual specimens of each one of the orders given on page 125 should be available to the pupils. Finally, some specimens which can be traced through to species should be used. The specimens representing these groups can be varied to meet local conditions. The foresighted teacher will have collected with the pupils on previous field trips, the specimens needed here. For directions for collecting and preserving insect specimens, see Farmers' Bulletin 1601 (1929), 5c.

The main ideas to be presented during the study of this problem are:

1. (*a*) The names chosen for animals usually describe these creatures in a general way.
b) The names are usually given in Greek or Latin (or a mixture of both) to avoid confusion that arises from local names.
2. The scientific method of classification is based upon likenesses and differences in physical structure.
3. Animals in general are classified according to *kingdom*, *phylum*, *class*, *order*, *family*, *genus*, and *species*.

SELF-TESTING EXERCISES (P. 127). 1. Insect has three pairs of legs, one or two pairs of wings. Spider has four pairs of legs, no wings, and simple eyes.

2. Have legs and other appendages that are jointed, hard, ex-

ternal skeletons, and three regions to the body which may be fused in some animals.

3. Number and characteristics of wings.
4. Genus and the species of genus to which it belongs.
5. Species, genus, family, order, class, phylum, kingdom.

PROBLEM 5: WHAT ARE THE DIFFERENT KINDS OF PLANTS? (P. 129)

The classification of plants is accomplished upon the same basis as that of animals—structural characteristics. This problem is provided for additional practice in separating living things into groups. However, the classification of plants is not given as much detailed consideration as is given to the classification of animals, since the structural details of plants are not usually so easy to observe. The suggestions given for the other four problems of the unit apply here and should be considered carefully in the presentation of this material.

Several specimens of living material of each of the groups *Thallophytes, Bryophytes, Pteridophytes,* and *Spermatophytes,* should be available and the pupils allowed to arrange these in their proper places on the "classification table" as the work proceeds. Separation of Thallophytes into *algae* and *fungi;* of Bryophytes into *mosses* and *liverworts* (much teacher help will be needed here); of Pteridophytes into fern plants, horsetails, and club mosses; and of Spermatophytes into *gymnosperms* and *angiosperms* (angiosperms into *monocots* and *dicots*) is a desirable procedure if a specimen of each group can be obtained. However, technical details are to be avoided at all times. Also, it should be called to the teacher's attention that in the Plant Kingdom the word *division* is usually substituted for the word *phylum,* which is used in the Animal Kingdom.

Experiment 51, page 443, of *Science Problems, Book 2,* may be repeated or recalled here, as the occasion demands.

The main idea to be presented during the study of this problem is that plants, as well as animals, are different in their body structures and are classified according to these differences.

SELF-TESTING EXERCISES (P. 138). 1. Characteristics of plant phyla (divisions):

PHYLUM	TRUE ROOTS, STEMS, LEAVES	VASCULAR BUNDLES	SEEDS
Thallophyte	No	No	No
Bryophyte	No	No	No
Pteridophyte	Yes	Yes	No
Spermatophyte	Yes	Yes	Yes

2. Plant that is all body, having no roots, stems or leaves.

3. Bryophyte has no true roots, stem, or leaves and no vascular system, while pteridophyte has these structures.

4. Produces seeds.

LOOKING BACK AT UNIT 2 (P. 138). 1. Responses will vary, but pupils should have become aware of likenesses and differences between certain animals and plants.

2. Responses will vary, but pupils should have acquired ability to classify animals and plants into large groups.

3. *Cilia:* tiny living hairs that move. They help certain protozoa move, help make water flow through sponges, etc.

Classify: group together things that are alike in some way according to some system.

Cold-blooded animal: animal whose body temperature changes *according to temperatures of its surroundings.*

Invertebrate animal: animal without a backbone.

Mammal: animal having hair on all or part of body, milk glands to feed young, and a body cavity divided into two parts by a diaphragm.

Phylum: the largest group into which plants or animals may be divided.

Rhizoid: threadlike structure that serves as a root in mosses and some other plants.

Structure: the way in which an animal or plant is put together.

Tentacle: slender, flexible appendage in animals that serves as organ of touch, etc.

Vertebrae: the many small bones that make up the backbone.

Vertebrate animals: animals with backbones.

Warm-blooded animals: animals whose body temperature remains the same regardless of the temperature of the surroundings.

LEGEND UNDER FIGURE 136 (P. 139). Arthropoda; Insecta; Coleoptera.

ADDITIONAL EXERCISES (P. 138). 2. (a) Try to determine from its most obvious external characteristics to what phylum it belongs. *b*) Determine class of phylum either by knowing characteristics of class or by using key given in some reference book. By following through key, genus and species of animal or plant can be determined.

3. Porifera, Annelida, Mollusca, Arthropoda, Vertebrates.

4. Protozoa, Annelida, Mollusca, Arthropoda, Vertebrates.

5. They have different structures.

10. (a) *Helpful: Thallophytes:* Many fungi and bacteria help in decay and thus return valuable materials to soil; bacteria and yeasts used in industrial processes; fungi used for food; useful products made from certain algae.

Bryophytes: Deposits of peat moss used as fuel.

Pteridophytes: Present-day members of group useful to man chiefly as ornaments, but huge ferns of the geologic past formed important part of coal deposits used as fuel today.

Spermatophytes: chief source of food for man and animals; wood for houses and countless useful articles, etc.

b) *Harmful:* fungi, spermatophytes.

BULLETINS AND PAMPHLETS FOR UNIT 2

Audubon Society, 1000 Fifth Avenue, New York, N. Y.
  Audubon Junior Club. Write for information about membership.
  Excellent illustrated nature bulletins and charts available.
Field Museum of Natural History, Chicago, Ill.
  Botany Leaflets
    Autumn Flowers and Fruits. 25c
    Common Trees. 25c
    Poison Ivy. 15c
    Spring Wild Flowers. 25c
    Spring and Early Summer Wild Flowers. 25c

Zoölogy Leaflets
  Mammals of the Chicago Area. 20c
  The Frogs and Toads of the Chicago Area. 25c
United States Department of Agriculture
  Agricultural Circular 143. *Some Common Mushrooms and How to Know Them.* 20c
  Miscellaneous Publication 295. *Famous Trees.* 20c
  Farmers' Bulletin 513. *Fifty Common Birds of Farm and Orchard.* 25c

VISUAL MATERIALS FOR UNIT 2

CHARTS

Church and Dwight Co., Inc. 70 Pine St., New York, N. Y.
  Two colored wall charts of native birds (free)

FILMSTRIPS

Society for Visual Education
  "Lizards, Snakes, and Turtles"
  "Frogs, Toads, and Salamanders"
  "Butterflies"
  "Moths"
  "Ferns and Horsetails"
  "Mushrooms and Toadstools"
  "Land Birds of North America"
  "Wild Flowers Everyone Should Know"

MOTION PICTURES

Encyclopaedia Britannica Films
  "Tiny Water Animals"
  "Beach and Sea Animals"
  "Some Water Insects"
  "Reptiles"
  "Animal Life"
  "Birds of Prey"
  "Some Seashore Animals"
  "Spiders"

PICTURES

Audubon Society, 1000 Fifth Avenue, New York, N. Y.
  50 post card pictures in color. Sets of 4. 50c a set.
Church and Dwight Co., Inc. 70 Pine St., New York, N. Y.
  4 different series of bird cards in color. 2×3 in. (free)

National Geographic Society, Washington, D. C.
Birds and Flowers. Colored plates in sets. Write for price list.

Singer Sewing Machine Co., 149 Broadway, New York, N. Y.
Pictures of American song birds with eggs. In color (free)

Wild Flower Preservation Society, 3740 Oliver St., N.W., Washington, D. C.
Post cards of habitats in color. 25c a dozen.

UNIT 3

How Are Plants and Animals Fitted to the Conditions Around Them?

FUNCTION AND SCOPE OF UNIT 3. The concept of adaptation, of fitness of living things to their functions and to their surroundings, is one of the great principles of biology. This concept is rather intuitively understood by most persons. For that reason, the initial interest of a class may not be high. Also, real comprehension requires some degree of analysis of environment and function as well as of structure. This analysis takes time and mental effort. Thus, in most cases, the teacher should expect that intelligent interest will develop only after some time has been spent on the unit. This effort is rewarded, however, by the satisfaction which most pupils gain in a working comprehension of the principle.

The average person should not only get satisfaction from seeing fitness in all living things about him; he should early grasp the fact that the human race must fit its environment or disappear in a relatively short period of time, that whatever in the individual or the race is contrary to adaptation is injurious in the long run.

This unit lends itself to wide individual observation rather than to the performance of demonstrations and the doing of experiments. Many specimens may be brought to the classroom to show adaptation. Excursions should be arranged to train pupils to look for adaptations even in their own back yards.

Pupils will more quickly grasp the significance of the unit if they have thought about the essential functions of living things and how they are carried out (*Science Problems, Book 1*, Units 8 and 9, and *Book 2*, Unit 8), about the principles of flotation (*Book 2*, Units 2 and 4), of heat control (*Book 2*, Unit 6), and of infection (*Book 2*, Unit 9).

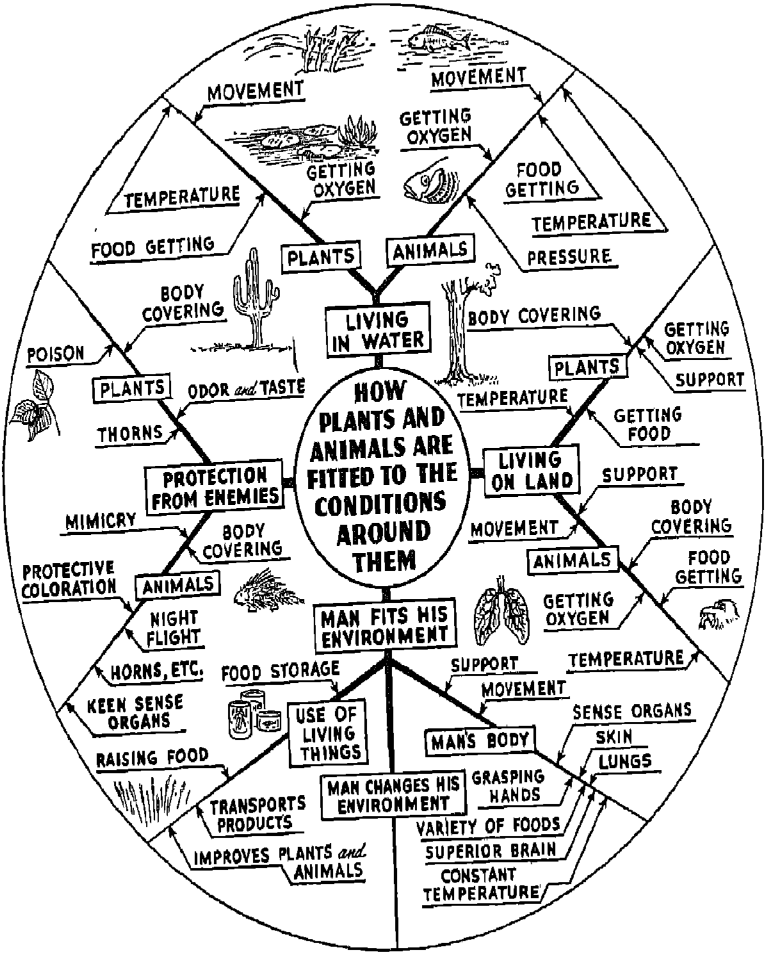


FIG. 3. GRAPH OF THE SUBJECT MATTER OF UNIT 3

INTRODUCTORY EXERCISES (P. 142). 1. Lists will vary. Following uses may be given: drinking, swimming, hiding, hibernating, source of food, bathing, laying eggs, and rearing young (as frogs do), as a habitat for all activities.

*2. Green plants must have light as source of energy in order to manufacture food by photosynthesis. Green plants are only living things that can make true foods, such as starch and sugar, from carbon dioxide and water. Must have sunlight to do this.

*3. Any fungi may be named. Examples are yeasts, bacteria, molds, mushrooms, etc.

4. Answers may vary. Any discussion should bring out advantages of living in water, such as plentiful water, food, support, and regular temperatures, and advantages of living in air, such as more light and oxygen.

*5. Answers will vary and should be judged on basis of quality. Green plants that live on land must have soil from which to get water and minerals and as support. Most animals must depend on green plants and thus indirectly on soil.

*6. Answer should be as much condensed as possible. Any habitat must provide sufficient water, food, oxygen, support, correct temperatures, shelter from enemies, etc.

7. Desert plants commonly have no leaves or very narrow leaves, thorns or prickles, hairy covering, etc. These devices reduce evaporation and protect plants from being eaten by animals.

9. Examples are plants that have prickles, thorns, unpleasant tastes, poisonous substances, etc. *Notice that three examples* are required, i.e., specific plants are to be named if possible.

10. Adaptations of man mentioned later in unit are: strong skeleton, legs and broad feet for land locomotion, grasping hands, protective skin, good lungs for air-breathing, voice and ears for communication, eyes for using light, warm body temperature, sweat glands for cooling the body, digestive system for many kinds of food, and thinking brain. He does not have warm body covering like many animals nor very rapid means of running.

*11. Such structures as proboscis, teeth, tongues of special types, claws and talons, sharp eyes, and sensitive smelling organs are mentioned in *Book 1*, Unit 9, as adaptation for getting food. For using food, are all the adaptations of digestive and circulatory organs.

LOOKING AHEAD TO UNIT 3 (P. 143). The preview is designed to stimulate inquiry and observation into the ways livings things are adapted, first, by breaking down the attitude of taking differences between organisms for granted and, second, by a brief analysis of the essential background for adaptation. The following points should be brought out by reading and discussion or in a talk by the teacher: (1) We commonly associate each kind of organism with a certain kind of place in which it lives—to which it is fitted. (2) There are on the earth a great many widely different habitats in which plants and animals live. (3) In each different habitat the living things through their adaptations must find the essentials for living. (4) The penalty for failing to be adapted is death.

PROBLEM 1: HOW ARE ANIMALS AND PLANTS FITTED TO LIVE IN WATER? (P. 147)

Consideration of adaptations to specific conditions is opened by study of water habitats, which are quite interesting to most boys and girls. Many of the adaptations to later life can also be readily demonstrated by having a few fish in a classroom aquarium and by a few fish obtained from a market. The main ideas are:

1. Water plants and animals take in dissolved oxygen through skin coverings or have special devices to enable them to get oxygen from the air at the surface. Some large water animals (the fish) have special thinly covered organs called gills for taking in oxygen by diffusion.
2. For rapid locomotion water animals are "streamlined" and have paddle-like "propellers."
3. Most water plants and animals are made in such a way that the lifting effect of the water holds them up; they do not need strong stems and legs.
4. True water animals are fitted to catch or strain floating food from the water.
5. Water temperatures do not shift rapidly nor go to the

extremes found on land; cold-blooded animals can be active in most water during the entire year; warm-blooded sea animals are covered with a layer of insulating fat.

6. Animals that live at great depths in the sea have special adaptations for catching food and seeing in the dark depths.

SELF-TESTING EXERCISES (P. 150). 1. By allowing dissolved gas to diffuse from water into bodies through skin coverings.

2. Fish have gills that expose great area of membranes to water. Action of mouth keeps current of water flowing over gills. From water, oxygen diffuses through membranes into fish's blood. (Common error is to apply term gill to slit where water comes out after passing over true gills.)

3. Mangrove roots send special branches up into air above water. Air passes down to lower roots through pores and passages in wood.

PROBLEMS TO SOLVE (P. 150). 1. To see fine structure of gills, it will usually be necessary to wash away mucus which thickly covers surfaces in fish that has been dead for some time.

2. Pupils should observe pumping action of mouth that sends water past gills and out slits at rear edges of gill covers.

3. Surfaces of gills would quickly become dry and then little oxygen could diffuse through coverings into blood.

SELF-TESTING EXERCISES (P. 156). 1. (a) Streamlined shape. b) Paddle-like propelling organs. Examples will vary.

2. Because the heavy water offers considerable resistance to arms and legs. Thus they push body forward as they push backward.

3. Muscle and bone are slightly heavier than water. Thus fish that is solid will sink. Bladder filled with air makes average density of fish equal to that of water.

4. Blubber is lighter than water and helps animals float. It is also good heat-insulating material and helps to hold animal's body heat inside it. (Fish do not need to keep bodies warm.)

5. Many water plants have air bladders or air spaces in their parts. Flexible stems are also advantage.

6. Air will not support plants noticeably because air is light. Thus stiff stems are needed to hold up leaves. Leaves and stems of water plants are held up by water (Archimedes' Principle).

PROBLEMS TO SOLVE (P. 156). 1. Inflating lungs causes body to displace more water allowing water to exert greater lifting force.

2. Feathers of ducks repel water because they are slightly oily. They thus remain filled with air, displace much water and cause water to hold duck up. If duck's feathers are made to absorb water by using some chemical in water, duck sinks.

3. Most fresh-water plants are buoyant because of air in leaves and stems. This will not be evident to casual observer. Many seaweeds have bladders.

4. Tail is used mainly as propeller, fins for guidance and control.

SELF-TESTING EXERCISES (P. 158). 1. For animals, much food is floating or swimming in water. Green plants require light, which is somewhat less abundant in water than on land.

2. More surface is exposed to light (and for absorbing dissolved carbon dioxide from water). They are also light in weight so that they float up toward surface where light is more abundant.

3. Hydras and relatives use poison "darts" and tentacles; clams and sponges strain food out of gentle currents; fishes and other animals pursue their food. Pupils' descriptions should be more complete.

SELF-TESTING EXERCISES (P. 160). 1. (a) Changes more slowly. b) Does not go as high or as low as on land.

2. In many cases they can be active at temperatures down to freezing, or they can hibernate and wait for warmer weather.

3. By having thick layers of fat on body just under skin.

SELF-TESTING EXERCISES (P. 163). 1. Light-producing organs, large mouths and eyes, queer projections.

2. They have always lived at that depth or have reached it slowly, so that all internal parts are adjusted to pressure outside.

PROBLEM TO SOLVE (P. 163). Investigation might well include divers, diving bells, caisson and tunnel work, etc.

SELF-TESTING EXERCISE (P. 165). Conditions stated in text are: greater buoyant effect of the surrounding fluid; greater resistance to motion; oxygen is dissolved rather than gaseous; no danger from evaporation; more floating food.

Problems to Solve (p. 165). 1-3. These are original exercises for pupils, and results will vary widely. The teacher should follow his own judgment in evaluating pupil responses.

PROBLEM 2: HOW ARE ANIMALS AND PLANTS FITTED TO LIVE ON LAND? (p. 166)

Although we take their adaptive features as a matter of course, land-dwelling organisms are not less well fitted for the conditions they must meet than are water organisms. This problem calls attention to several significant types of adaptations found in the organisms. The following ideas are emphasized:

1. Land organisms must be fitted to support their own weight (and, if animals, to move about), to keep from drying out, to obtain oxygen from air, and to meet extremes of temperature.
2. Strong legs with stiff skeletons and muscles enable land animals to support themselves, travel about, and obtain food.
3. Light construction, "streamlined" shape, and feathered wings fit birds for locomotion in air.
4. Most land plants have in their stems and leaves stiffening materials to hold them up in the air.
5. Land animals have abundant oxygen-absorbing surfaces hidden within lungs or air tubes; movements constantly keep fresh air in the spaces.
6. Plants have an abundance of breathing pores in their leaves and stems.
7. To prevent death from drying out, land organisms have special water-obtaining structures, waterproof coverings, and often special water-storage facilities.
8. Animals meet temperature extremes in different ways. Insulating materials, cooling by evaporation, and hibernation are all used.

Self-Testing Exercises (p. 170). 1. (a) Less resistance to forward movement; (b) less resistance to propelling organs; therefore, they must in most cases push against ground; (c) support of air is much less than that of water.

2. Few by lying flat on ground; most by means of column-like legs which contain a strong framework and strong muscles.

3. By special stiffening structures in their stems such as tough fibers and wood.

4. By light weight, streamlined shape, feathered wings and tail.

PROBLEMS TO SOLVE (P. 170). 1. Flying squirrels do not really fly. Have flaps or folds of skin that extend from front to rear legs forming kind of wings on which they glide from high places to lower ones. Large amount of hair on tail and arrangement of hair backward on body also helps. Flying fishes have wing-like fins on which they glide in air after gaining considerable speed in water.

2. There is so much less friction on ice.

3-4. Pupils will find helpful material on these problems in many different reference books. There is also opportunity for observing characteristics and drawing conclusions for themselves.

SELF-TESTING EXERCISES (P. 175). 1. Water is an essential part of all protoplasm. Air about them is often not very moist. Therefore, if not protected, the essential water might soon evaporate.

2. Animals adapted to dry places have thick waterproof skins and often covering of hair or feathers that retards evaporation.

3. One reason is that they dry out too rapidly. (Another probable reason is that rays of sun are themselves harmful.)

4. Camel has places for abundant stores of food and water in body. Shaggy coat, padded feet, protected nostrils and eyes are all helpful.

5. Common land plants are covered with epidermis and often with waterproofing on epidermis. Guard cells can close pores in epidermis when leaves begin to get too dry. Desert plants have reduced amount of surface.

PROBLEMS TO SOLVE (P. 175). 1. Frog's skin is thin and needs to be kept moist because it needs to obtain part of its oxygen supply through its skin.

2. Main reason is probably that fresh air cannot get to gills to let oxygen soak into blood and let carbon dioxide out.

3. There is probably less evaporation from lower side. Also, there is less possibility of pores being closed by dust settling on leaf surface.

5. Hairs cause slower air movement near surface, and thus water vapor is not carried away so rapidly.

SELF-TESTING EXERCISES (P. 177). 1. Because comparatively little food would come to it through air, certainly not enough to support large animal. (Some insects and spiders do set "traps" or lie in wait in one place for other insects to come to them.)

2. In having waterproof epidermis, stomata, well-developed vascular system, and extensive root system.

SELF-TESTING EXERCISES (P. 180). 1. (a) By more rapid oxidation and by sending little blood to skin. (b) By slower oxidation, by sending more blood to skin and by pouring out perspiration to evaporate from skin and cool it.

2. By heavy layers of fat and fur.

3. Many plants shed their leaves in cold weather apparently to avoid loss of water through them (at a time when little food could be made). Plants that keep leaves in winter have narrow leaves with heavy covering.

4. By migration birds and other animals can go to places where food supply is abundant and where temperature conditions are more favorable. (NOTE: This exercise is not discussed in the reading material, but the answer is suggested in the legend under Figure 172, page 180.)

5. Hibernating animals do not need to keep as warm as active animals and can go for a long time without food at times when food is scarce.

6. This comparison can be made more definite if it is done by making a table. Pupils will probably not find all points included.

CONDITION	WATER HABITAT	LAND HABITAT
Lifting effect of surrounding material	Great	Little
Resistance to motion through surrounding material	Great	Little
Temperature changes	Slow; not extreme	Rapid and extreme
Oxygen supply	Dissolved in water	Abundant; gaseous
Loss of water by evaporation	None	Often serious
Floating food supply	Rather abundant	Limited
Light	Reduced by water	Usually abundant

7. Such an animal is unable to move about on land, to get adequate oxygen, and to prevent evaporation of water.

8. Cannot swim efficiently and, more important, it cannot get enough oxygen from water.

PROBLEMS TO SOLVE (P. 181). 1. This list will include bears, woodchucks, some insects, frogs, turtles, snakes, toads. It may be easily extended to much greater length.

2. Migratory animals are mainly birds. However, a few insects, such as monarch butterfly, some bats, and some mammals such as caribou, elk and reindeer migrate regularly.

3. Feathers are fluffed out, and often birds find protected or sunny spots in which to remain.

5. Aestivation corresponds to hibernation but occurs during hot or dry weather usually because of drouth and lack of plant or other food which results.

6. Adaptations of dandelion include deep root which can start new leaves if cut off, low-lying leaves that escape lawn mower and kill off neighboring grass by shading it, a low-lying blossom but a raised seed stalk to start seeds off in wind, many seeds with "parachutes" to float in wind, and others.

8. Toads must go back to water to lay and fertilize their eggs and let tadpoles develop.

PROBLEM 3: HOW DO THE STRUCTURES OF LIVING THINGS PROTECT THEM FROM THEIR ENEMIES? (P. 182)

This problem brings out a third essential aspect of adaptation, that of protection. Protective adaptations are of special interest to most people. The teacher may well capitalize on this natural interest, while broadening his pupils' general knowledge of the extent and nature of adaptations. The main ideas brought out in the discussion of Problem 3 are:

1. Animals are commonly protected by various kinds of armor, by coloring that makes them inconspicuous, by means of escape, and by offensive weapons.

2. Plants are protected against animals and other enemies by their outer covering, which often bears thorns.

Self-Testing Exercises (p. 189). 1. Three ways emphasized in discussion are: protective outer covering or "armor," protective coloring, means of flight, weapons for fighting. Many, many examples of each may be found by reading and observation.

2. (a) Light and dark-colored fish were put in pool with light bottom like natural home of former. Then birds were allowed to catch fish for a time. More of dark-colored fish were caught.
b) Both kinds of fish were put in dark-colored pool, similar to natural home of dark fish, and experiment was repeated. This time more of light-colored fish were caught.

3. Tough or injurious outer coverings, thorns, hairs, bad taste or odor, poisonous substances.

Problems to Solve (p. 190). 1-3. All three problems require actual observation, the first two being suitable for rural districts, and the third for both rural and city communities. In rural districts, Problem to Solve 3 may be directed toward a study of the most persistent weeds in the cultivated fields. All three problems are best carried out during the growing season or in early autumn.

PROBLEM 4: HOW DO WE FIT OUR ENVIRONMENT? (p. 190)

Study of man's adaptations after those of plants and animals allows pupils to get a new point of view toward the human race. The discussion brings out the following main ideas:

1. Men live in a greater variety of land habitats than most living things.
2. Man's body is reasonably well fitted for land life in other ways, but it possesses three outstanding features: (a) ability to use many kinds of foods, (b) hands that hold and manipulate objects, and (c) a thinking brain.
3. Man improves and uses the adaptations of plants and animals for protection, food production, etc.
4. Man changes his environment in what he thinks are desirable ways; in this respect he is often short-sighted.

Self-Testing Exercises (p. 196). 1. Man can live in much wider habitat than most kinds of living things. This is due to his ability to eat various kinds of food, to use adaptations of plants and animals, and to change natural environment for his own good.

2. Any common animal may be chosen. If the comparison is with dog, following might be mentioned: (a) strong legs for support and locomotion, tough skin, efficient lungs, voice, and ears for communication, good eyes, good sense of smell, temperature regulating body; (b) less ability to run fast, less delicate sense of smell, ability to speak, grasping hands, better brain, poorer body covering, etc.

3. Following may be mentioned (three are called for): warm coverings such as furs; food-producing ability of cows; rapid locomotion and endurance of horses; hunting ability of dogs; strength of tree trunks; water-shedding ability of leaves.

4. (a) More even temperature (inside buildings); dryer; fewer dangerous mammals; more food animals; different kinds of plants; more comfortable sleeping places; fewer insects.
b) Probably not unless one could find a naturally warm place in which to rest. Winter temperatures are too low for human body to withstand without clothing or other artificial protection. Rain and snow cause added difficulty in keeping warm.

PROBLEMS TO SOLVE (P. 197). 1. Various illustrations of the following may be given: constructing or excavating shelters; collecting and storing food; clustering together for warmth; making pathways.

2. Growth of plants shades ground, reduces movement of air near surface, reduces temperature in sunlight, increases humidity, prevents rapid run-off of surface moisture after rains, adds humus and various other substances to soil.

3. Social animals can build more adequate shelters, store food more effectively, keep warm more easily, give better protection to their young, better protect themselves against active attacks of enemies. These advantages are in part due to specialization and division of labor, especially among insects.

LOOKING BACK AT UNIT 3 (P. 197). 1. Pupils may understand this assignment better if they are asked to list new ideas they have gained. It may well be started as a class exercise in which several pupils are asked to state one new idea each. As they are stated, their new ideas may be listed on the blackboard by the teacher.

When the class has begun to think actively, pupils may be asked to list their new ideas separately on paper. Later, a composite list may be made.

2. Paragraphs for each problem should include most of the main ideas listed in this *Guidebook* at the beginning of each problem, pages 98, 101, 104, and 105.

3. *Adaptation:* some feature of structure or behavior that fits plant or animal or human being to keep itself or its offspring alive. May also be act of fitting oneself to situation.

Mimicry: imitation. Some animals are colored and shaped like other things in their surroundings so that they will pass unnoticed or will not be attacked by their enemies. Such animals are said to possess mimicry.

Gill rakers: comb-like structures on gill bars of fish that help direct food into esophagus while water flows out between gills.

Habitat: place or kind of place in which plant or animal lives.

Hibernation: "sleeping" through cold weather, as is done by frogs, bears, and many insects.

Lenticel: breathing pore on plant stem. Lenticels are visible on young stems as tiny dots.

Migration: traveling from one place to another, usually in groups, as in the case of birds that go south for winter and north for summer.

Phosphorescent organ: organ that gives out light or glows in the dark. Examples are abdomen of fireflies and special glowing organs of deep-sea fish.

Protective coloration: any kind of coloring that helps protect animal from being attacked or helps it get food by making it inconspicuous.

Additional Exercises (p. 197). 1. In case the teacher deems it advisable, pupils who have time may be referred to pages 641-643 of the text for reading on this topic.

5. Adaptation means being fitted to the situation. When animal eats right kind of food, finds warm sheltered place to sleep, runs from danger, protects and feeds its young, it is doing thing that fits situation. In same way, turning of roots downward or toward moist earth, of leaves toward light, of tendrils about supports are adaptations of plants to situation in which they live.

6. Low temperatures prevent food-making by leaves in wintertime and also prevent roots from taking in moisture. By shedding leaves, plants keep themselves from drying out through leaves. Thus scientists believe shedding of leaves is adaptation to winter condition.

7. Most evergreen leaves are narrow and protected in other ways from drying out. They also contain resinous sap rather than watery sap, so that they are not so greatly injured by freezing.

8. Herbaceous plants grow and produce seed in few months, and then young plants live over winter ("hibernate") in seeds where they are not injured by low temperatures or drying, and where they can be easily scattered to many places.

Trees hold leaves and flowers high in air, cover wide areas with roots, start summer with well-established root system and large store of food. They are not so easily destroyed by animals as is single small plant.

9. Alpine plants are characterized by creeping or prostrate habits, thick or hairy epidermis to reduce evaporation, and, in trees and shrubs, reduced stems. In polar regions much the same adaptations are found. Plants are either annuals which grow and mature seed quickly or low-growing forms which are protected by snow during winter.

10. Man can best live without fire in warm countries. Winter, in cold and cool temperate parts of the world, is so cold that people can seldom survive without warmth of fire.

BULLETINS AND PAMPHLETS FOR UNIT 3

American Museum of Natural History, New York, N. Y.
  School Nature League Bulletins. 5c
    Bird Migration
    Mammals in Winter
    Teeth and Claws
United States Department of Agriculture
  Farmers' Bulletin No. 660. *Weeds, How to Control Them, with Descriptive List of 50 Worst Weeds.* 5c
  Journal of Agricultural Research (Reprint 1938). Vol. 56, No. 12. Iowa-28. *Control of Dandelions in Lawns.* 5c

VISUAL MATERIALS FOR UNIT 3

FILMSTRIPS

Society for Visual Education

- "How Color Protects Animals"
- "Some Desert Animals and How They Live"
- "How Animals Protect Themselves"
- "Beaks and Feet of Birds"
- "Wings and Feet of Birds"
- "Migration of Birds"
- "Structure and Bill"
- "Some Plants of California Deserts"

MOTION PICTURES

Encyclopaedia Britannica Films

- "Frogs, Toads, and Salamanders"
- "Frog"
- "How Nature Protects Animals"
- "Birds of Prey"
- "Under-Sea Life"
- "Seals and Walruses"
- "Beach and Sea Animals"
- "Tiny Water Animals"
- "Snapping Turtle"

UNIT 4

How Do Simple Machines Help Us Do Work?

Function and Scope of Unit 4. The preceding subject matter of the book has dealt entirely with biological topics. This unit is the first of a series of six devoted to the physical sciences and focused on the general topic of man's utilization of energy. To most pupils the ninth grade is the terminal year of science instruction. Any adequate treatment of such topics as electricity, light, power machines, etc., calls for the greatest possible maturity on the part of the learner. Therefore, the subject matter of these six units has been allocated to the last book of the series.

As indicated by the asterisked Introductory Exercises (Nos. 1, 2, 3, 4, 5, and 7), the unit assumes certain prior understandings regarding the nature of force and energy. These were fully treated in Units 2 and 5 of *Science Problems, Book 2*. While there is a certain amount of reteaching in Book 3, the teacher should be sure, by review if necessary, that the basic concepts relating to force and energy are clear in the pupils' minds.

Unit 4 is focused upon man's use of simple mechanical devices in overcoming the natural forces which he encounters in his everyday existence: moving a heavy object from one place to another, cutting materials, changing the direction of some force, and increasing the speed and efficiency of performing simple tasks. The study of simple machines is strategically placed at this point in the course to provide means for a better understanding of the use of complex machines, treated in Unit 9. It is these complex machines which make possible modern communication and transportation and which aid in harnessing natural forces more effectively.

The teacher should be particularly careful in the following aspects of the study: (1) He should see that the pupils develop a thorough understanding of the scientific meaning of work. (2) He should see that the pupils do not merely repeat memo-

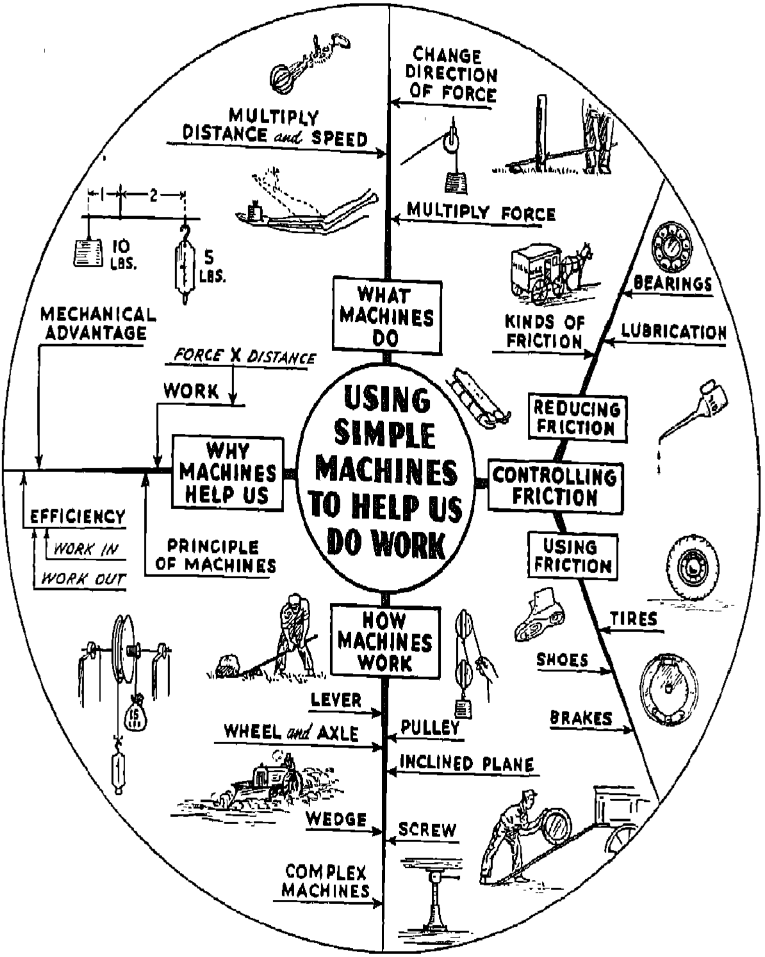


FIG. 4. GRAPH OF THE SUBJECT MATTER OF UNIT 4

rized definitions. He can do this by having the pupils express in their own words the ideas which they have gained. For example, pupils can easily repeat that "the distance from weight to the fulcrum is the weight-arm," and "the distance from the force to the fulcrum is the force-arm" without having any real knowledge of what is actually meant. (3) The teacher should use the mathematical treatment of the principles of simple machines as it is presented in the text for illustrative purposes only. Not all pupils at this level should be expected to work complicated theoretical problems in finding how much force will be needed to lift a given weight, etc. (4) The teacher should require application of the principles of the unit to the everyday use of simple labor-saving devices in order to make the work real to the pupils.

INTRODUCTORY EXERCISES (P. 200). *1. Capacity to do work, to exert force through distance, to make things happen to matter. (a) Bent bow has stored energy because of its elasticity. Can make an arrow move through the air. (b) Wound-up clock spring has stored energy, usually of muscles, because of its elasticity. Can make clock wheels move. (c) Lifted weight has stored energy because of its position. Can smash and move things when it falls and strikes them.

*2. (a) Inertia of motion. (b) Inertia of rest.

*3. A push or pull on matter regardless of whether matter moves.

*4. Gravity. Force that holds molecules of matter together.

*5. No. Work is done only when a force moves an object through a distance.

6. Pulleys, inclined plane, wheel and axle. Could be used singly or in combination. Lift straight up with rope and pulleys and swing over to stage or pull up inclined plane with pulleys or with windlass. Rollers could be used with inclined plane.

*7. Friction is the resistance that two materials in contact encounter when they move past each other. Friction makes necessary more force to run a machine and causes moving parts of machines to wear out. However, it enables us to stop machines, to grind, cut, and polish materials, to start trains, automobiles, etc.

9. Any kind of simple device that helps us do work, that is, that helps us use force to move, cut, and shape materials.
10. Distance from support to small boy greater than distance from support to larger boy.

LOOKING AHEAD TO UNIT 4 (P. 201). An effective and interesting way of introducing this unit is to bring to class many different kinds of simple machines, such as a hammer, an egg beater, a tack-puller, a pair of pliers, a screw driver, scissors, and a nutcracker. Use the material on these pages to form the basis of a brief stimulating talk to the pupils for the purpose of arousing interest and of giving them an insight into the material that is to follow. Use the simple machines that have been brought to class to illustrate the talk and to stimulate questions from the pupils, but do not attempt the answers at this point. Save the questions for use as the unit develops.

During this introduction the following points should be made clear to the pupils: (1) What a machine is. (2) Scientists can put machines into classes, and "by learning how a representative machine of a given class works, you will understand the principle upon which all machines of that class work?" (3) Everyone should understand how simple machines operate, since all of us depend upon them to such a great extent.

PROBLEM 1: WHAT ARE MACHINES USED FOR? (P. 205)

The idea of the importance of machines in daily living should become a part of the pupils' thinking as early in the unit as is possible, since modern living could not go on without the use of machines in terms of highly complicated devices such as sewing machines, locomotives, and tractors. Consequently, in this first problem of the unit the pupil should be made aware that the many, simple, everyday, labor-saving devices are machines just as truly as are the more complicated devices.

Few pupils will have clear ideas of what machines are used for. The general conception is likely to be that we use machines to help make our work easier, but there will undoubtedly be much hazy and inaccurate thinking as to how this is accomplished.

Therefore, during the study of this problem the following main ideas should receive particular emphasis:

1. Every kind of machine we use helps us to overcome some kind of resistance, as gravity, friction, inertia, etc.
2. Machines help us do work by multiplying the force we use to operate these machines.
3. Machines multiply the speed with which we can move objects and enable us to move objects greater distances.
4. Machines may change the direction in which forces act.
5. Machines may be used to store energy.
6. Machines are used to transmit force from one place to another.

SELF-TESTING EXERCISES (P. 211). 1. Almost every kind of work done in the world involves use of some kind of machine.

3. *Sailboat:* hammer, saw, plane, brace and bit, screw driver, clamps, etc. *House:* broom, mop, vacuum cleaner, rug-beater, tack-hammer, etc. *Bicycle:* wrench, screw driver, file, hacksaw, pliers, etc.

4. *Gravity:* pulleys, levers.
Inertia: baseball bat, tennis racket, automobile transmission gears.
Molecules: saws, knives, wedges, hammers.
Friction: automobile engine, steam engine.
Elasticity: clock key or watch stem, clothes wringer, lemon squeezer.

SELF-TESTING EXERCISES (P. 216). 1. Answers are individual but may include using crowbars, automobile jacks, planks, etc.

2. Diagram should show one hand held near the lower end of the fish pole and the other hand on the lower end. As the upper hand moves a short distance, the fish on the end of the line moves a much greater distance.

If your hand moves through a certain distance, the end of the pole with the fish on it moves through a greater distance at the same time. Therefore, it moves faster than your hand.

3. Diagrams will include crowbars, pulleys, gears, etc.
4. To store energy.
5. Diagram may show belt, pulley, gear, etc.

PROBLEMS TO SOLVE (P. 217). 1. By multiplying our force. The hammer handle is moved a greater distance than the claw.

2. Usually by gears.
3. Sometimes by belt, sometimes by direct connection with shaft (armature) of motor.
4. By sets of gears.

PROBLEM 2: WHY DO MACHINES HELP US DO WORK? (P. 217)

A common misconception about work is that it is any unpleasant or tiring physical or mental activity. Since this problem deals with work in the scientific sense, it is well for the teacher to be certain that the pupils understand clearly (after having studied the unit thus far) the definition of the kinds of devices used in doing physical work: A machine is simply a device which uses energy to do work more effectively than it could otherwise be done. With this understanding clearly in mind, it will then be easy for the pupils to understand what work is according to the scientific interpretation.

This problem also provides the basic understandings for clearing up another common misconception about machines and work: Machines do not "save work," as is so often stated, for no machine has one-hundred per cent efficiency. Thus the teacher should stress thoroughly until all of the pupils understand it that machines help us by making our work easier to do. Mechanical advantage is presented simply as a measure of how much machines help us in overcoming forces. The important ideas of the problem are as follows:

1. Work is done when a force is exerted through a distance.
2. The amount of work done depends upon the force that is exerted and the distance through which the force acts.
3. The amount of work accomplished does not depend upon the speed at which the work is done.
4. The amount of work necessary for the operation of a machine is always greater than the amount of work done by the machine.
5. Machines are able to exert large forces over short distances by exerting small forces over large distances.

6. The mechanical advantage of a machine may be found by dividing the force exerted by the machine by the force exerted on it.

SELF-TESTING EXERCISES (P. 220). 1. No. Work is done only when a force overcomes some resistance and thus moves something.

2. Answers will vary. They must include the idea of a force moving an object through a distance.

3. They would both do the same amount of work regardless of how long it took. The rate of doing work does not determine the amount of work done. Ten 100-pound sacks of flour weigh exactly the same as 20 fifty-pound sacks.

PROBLEMS TO SOLVE (P. 220). 1. No work. You held the object stationary. To do work, you must move an object through a distance.

2. The horse is working while it is pulling the wagon. The horse is not working when it is merely keeping the wagon from rolling downhill.

3. With a draw scale or some other device measure the force required to move the boat and multiply by the distance moved in feet (10). This will tell how many foot-pounds of work were done in moving the boat.

4. 595 foot-pounds (7 × 85).

5. Answer will depend on pupil's weight. Multiply weight in pounds by 15 feet to get work done (foot-pounds).

EXPERIMENT 7. DOES IT REQUIRE LESS WORK TO ROLL AN OBJECT UP A PLANK THAN TO LIFT THE OBJECT THE SAME DISTANCE? (P. 221). Apparatus and materials needed for the experiment are:

Smooth board five feet long and one foot wide
Support for holding one end of board two feet above top of table
Spring scale
Oil for wheels
Small wagon or cart whose wheels turn with least friction possible
Enough small weights of iron, stone, or sand to make cart and weights weigh ten pounds

Be certain that the cart is pulled along the plank slowly and at a uniform rate of speed. Have the direction of the pull parallel to the surface of the plank.

The work done by the pupil pulling the cart up the plank is found by multiplying the force exerted (reading shown on spring scale) by the distance through which the cart moved. The work done by the machine is found by multiplying the weight of the cart and its contents by the height to which it was raised above the table. Because of friction, the amount of work done in pulling the cart up the plank to a height of two feet above the table top is always greater than the amount of work done in lifting the cart and its contents the same distance. Thus machines do not save work.

Self-Testing Exercises (p. 223). 1. Answers will depend on the data from the experiment. In no case, however, will the work out exceed or equal the work in.

2. Of the work put into the machine only half results in work done.

3. No. There is always some friction in a machine; therefore, we must always put in enough work to overcome friction, in addition to what we will get out.

Problems to Solve (p. 224). 1. 600 foot-pounds (3 × 200).
2. 620 foot-pounds (10 × 62). About 97% (600 ÷ 620 × 100).

Self-Testing Exercises (p. 226). 1. Because a machine makes work easier by multiplying our force, changing the direction of our force, or by multiplying its speed and distance.

2. The amount of help we get from a machine. It can be found by dividing the weight lifted by the force needed to lift it or by dividing the distance the force moved by the distance the weight moved.

3. 10 (100 ÷ 10).

4. The machine makes it possible for a small force moving a great distance to lift a large weight through a short distance.

Problems to Solve (p. 227). 1. 12 feet long (200 × 3 ÷ 50).
2. 4 (12 ÷ 3); 25 pounds (100 ÷ 4).

PROBLEM 3: WHAT ARE THE KINDS OF SIMPLE MACHINES? (P. 227)

Up to this point the pupils will have learned what work is (according to the scientific definition), what a simple machine is, ways in which machines help us do work, that machines do not save work (although they make it easier to do and aid in doing it effectively), and why machines are able to exert such large forces. With this ample background the pupils are ready for a more detailed study, which will enable them to classify simple machines into their six groups and to understand more easily the principle upon which each of these groups operates.

Analyses of a few complex machines are made at the close of the problem to show that these machines are merely combinations of simple machines. This procedure is used to provide for more complete understanding of how natural energy is harnessed to do work (Unit 9) and of the use of mechanical principles in obtaining electrical currents (Unit 5). The main ideas to be stressed are:

1. A lever is a handle or a bar that can exert force by turning about a fixed point or support (fulcrum).

a) Some levers have the support between the force and the weight (first class).

b) Some levers have the weight placed between the support and the force (second class).

c) In some levers the force is exerted between the weight and the support (third class).

2. Levers in which the force is exerted between the weight and the support have the mechanical advantage of speed and distance because the weight moves more rapidly and through a greater distance than the force moves.

3. The advantage of a single fixed pulley is that it changes the direction in which the force is exerted.

4. A single movable pulley has a mechanical advantage of two because the force moves twice as far as the weight.

5. A combination of pulleys known as a block and tackle

exerts a small force through a great distance to move a large weight through a short distance.

6. A crank or wheel attached to a smaller wheel or axle forms a simple machine called a wheel and axle which is used to multiply force or speed.

7. An inclined plane makes it possible to lift a heavy weight a short distance by using a small force to move the weight a greater distance along the plane.

8. A screw is a kind of inclined plane (an inclined plane which is wrapped around a cylinder).

9. A wedge is a kind of inclined plane which can force materials apart.

10. By means of a wheel and axle a multiplication of force or of speed and distance may be obtained.

11. Complex machines are made of combinations of simple machines which work together.

EXPERIMENT 8. HOW DO LEVERS WORK? (P. 227). Apparatus and materials needed are:

Bar or straight stick 3 ft. long for a lever (a yardstick will do)
Support for lever
Two yardsticks
Spring scale
5-pound weight (a bag or bucket of sand; sand plus container should weigh 5 pounds)

a) The lever is explained in terms of the machine principle instead of by the principle of movement of force. It is the authors' experience that pupils of this level grasp the idea of the machine principle much more easily and that the movement-of-force explanation is better suited to higher levels of maturity.

The apparatus arrangement in this part of the experiment is a simple balance, which is a kind of lever. The force needed to lift the weight is approximately the same as the weight. The force moves through the same distance that the weight moves. The mechanical advantage is 1.

b) The small force moving through a greater distance lifts the weight a small distance.

Supplementary experiments may be done by rigging up and using second- and third-class levers.

SELF-TESTING EXERCISES (P. 231). 1. Drawing may show a lever 6 feet long. The distance from the stone to the fulcrum should be 1 foot; and from the fulcrum to the force, 5 feet. (If length is different the 1 to 5 proportions should be maintained.) The mechanical advantage is 5. The force-arm is five times as long as the weight-arm; this ratio is theoretically the same as the mechanical advantage.

2. If the small force is moved a great distance, the heavy weight will be moved a short distance. The lever multiplies force or has a mechanical advantage.

3. Sketches should show three arrangements: (a) The fulcrum is between the force-arm and the weight-arm. It will multiply force if the force-arm is longer than the weight-arm; it will multiply speed and distance if the weight-arm is longer than the force-arm. (*b*) The fulcrum is at one end and the force at the other with the weight in between. It multiplies force. (c) The fulcrum is at one end and the weight at the other with the force in between. It multiplies speed and distance.

PROBLEMS TO SOLVE (P. 231). 1. Refer to the answer to Exercise 3 above. Only the first arrangement will change the direction of force.

2. Close to your shoulder. From bag to shoulder (fulcrum) is the weight-arm, and from shoulder to hand is the force-arm. The shorter the weight-arm, the longer the force-arm, and the greater the mechanical advantage. Less force is required to hold the stick down and the bag up.

3. The key is a lever in which the force is applied at one end and the fulcrum is at the other with the weight in between. Since the force-arm is longer than the weight-arm, the lever gives an advantage of force.

4. Tin and metal shears need an advantage of force because it is hard to cut through tin and metal. Having the handles (force-arms) longer than the blades (weight-arms) gives an advantage of force. But paper is easy to cut. Therefore, paper shears have short handles and long blades. This gives an advantage of speed and distance.

5. Near wheel to make force-arm (wheelbarrow handles) as long as possible and thus reduce pull on arms.

EXPERIMENT 9. HOW DO PULLEYS WORK? (P. 232). Apparatus and materials needed are:

Single pulley
Two combination pulleys
Yardstick
Support that will hold pulley at least 3 ft. above top of table
5-pound weight (a pail or bag of sand, container and contents weighing 5 lb.)
About 10 ft. of strong cord
Spring scale

a) The weight moves the same distance the force moves. The force needed to lift the five-pound weight is five pounds. The mechanical advantage is 1. The real advantage is that a single movable pulley changes the direction of force.

b) The container, weight, and pulley should weigh five pounds in this part of the experiment. The pulley is considered a part of the weight because it moves upward as the weight moves upward. The pull should be as nearly vertical as possible and at a uniform rate of speed. Have the scale read as it is moving upward. The force moves twice as far as the weight. The force needed to lift the weight is half as great as the weight. The mechanical advantage is 2.

c) With the apparatus shown in Figure 221 the weight moves upward. The force moves four times as far as the weight. The mechanical advantage is 4.

SELF-TESTING EXERCISES (P. 235). 1. Examples will vary but may include any situation in which the direction of force is to be changed.

2. Drawing should show a five-strand arrangement like the second from the right in Figure 223, page 235. If the boat is lifted 4 feet, the rope must be pulled 20 feet (300 ÷ 60 × 4). The mechanical advantage is 5 (300 ÷ 60, or 20 ÷ 4).

EXPERIMENT 10. HOW DOES A WHEEL AND AXLE MAKE WORK EASIER? (P. 236). Apparatus and materials needed are:

Home-made apparatus (Fig. 225)
Clamp
Spring scale
Two long strong cords
Weight and container which together weigh 15 lb.

Fasten a piece of cord to the large wheel by a nail driven in the rim of the wheel. Attach the scale to the free end of the cord as shown, Figure 225. Fasten a piece of cord to the small wheel by means of a nail. Attach the weight to the free end of the cord. Slightly more than three pounds of force are needed to lift the fifteen-pound weight. The force travels five times as far as the weight. The mechanical advantage is 5.

SELF-TESTING EXERCISES (P. 238). 1. By using a larger wheel or a smaller axle or both.

2. The steering-wheel is a wheel and axle. The greater the diameter of the wheel, the greater the mechanical advantage, and the less the force required to turn the wheels of the car.

SELF-TESTING EXERCISES (P. 240). 1. A handle 3 feet long. The longer the handle, the greater the distance through which the force must move, and the greater the mechanical advantage.

2. Force moves through a much greater distance than weight lifted. As force moves around circumference of big circle made by handle, weight is lifted only the small distance between threads on screw.

PROBLEMS TO SOLVE (P. 241). 1. Handle of a wrench moves in a big circle around nut on bolt, while your fingers move in a much smaller circle. The greater the distance through which the force moves, the greater the mechanical advantage.

2. Drawings may vary, but they should show the vise closed by a screw. You can clamp objects so tightly in a vise because the screw with its lever handle has such a great mechanical advantage.

SELF-TESTING EXERCISES (P. 242). 1. The material being forced apart by a wedge squeezes tightly against the wedge. Great friction between wedge and material reduces efficiency greatly.

2. A long, thin wedge. The longer the slope of the wedge and the narrower the top, the greater the mechanical advantage will be.

PROBLEMS TO SOLVE (P. 242). 1. Measurements will vary. A wider pitch will make jack harder to operate because weight must be lifted more for each turn of handle, thus reducing mechanical advantage.

2. 200 pounds with a single movable pulley; 100 pounds with a single fixed pulley. With a single movable pulley the force moves twice as far as the weight; therefore, it has a mechanical advantage

of 2. (2 × 100 = 200). With a single fixed pulley force and weight move same distance; only direction of force is changed. The mechanical advantage is 1. (1 × 100 = 100).

3. (*a*) 6 (36 ÷ 6); (*b*) 600 pounds (6 × 100).

4. About 45,240 pounds (36 × 2 × 3.1416 ÷ ¼ × 50).

SELF-TESTING EXERCISES (P. 246). 1. In one machine we can have a combination that greatly multiplies force or speed and distance and also changes direction of force.

2. Move the part where the force is applied a certain distance. Then measure distance working part (weight) moved. Divide first distance by second to get mechanical advantage.

PROBLEMS TO SOLVE (P. 246). 1. About 29⅓ feet, or 352 inches (8 ÷ 2 × 28 × 3.1416).

2. A high-gear bicycle has a large front sprocket wheel and a small rear sprocket wheel, thus getting a great multiplication of speed and distance. A low-gear bicycle has a smaller front sprocket wheel and a larger rear sprocket wheel (though of course the front is still larger than the rear). This arrangement gives less multiplication of speed and distance, but less force is required in going up hills.

3. The one in which the back wheel goes around 3½ times while the pedals go around once. Although this bicycle would not have the multiplication of speed and distance of the other, less force would be required in pedaling up hills. The shorter the distance the back wheel moves, the less force required to move it.

4. *Wheels and axles:* clothes wringer, washing machine, ice-cream freezer, grindstone, door knob, key (also some types of can openers). *Levers:* broom, sugar tongs, shovel, can opener.

5. Most automobiles now have hydraulic brakes. The brake pedal is a lever. The brake shoes are forced against the brake drums by an arrangement of levers. The mechanical advantage is high.

PROBLEM 4: HOW DO WE CONTROL FRICTION IN OUR MACHINES? (P. 247)

Thus far friction has been mentioned chiefly as keeping machines from being 100 per cent efficient. In this problem friction is treated in some detail as being both helpful and harmful. The major emphasis, in the light of the problem title and of the nature of this unit, should be upon reducing friction in making the work of our machines more efficient. However, it is likely that many pupils will not have considered the helpful aspects of friction at all. Thus, the latter part of the problem and its applications may prove to be new and interesting material and should be thoroughly developed for its full value. The main ideas of this problem are:

1. Because of friction between its moving parts, no machine is 100 per cent efficient.
2. Sliding friction occurs when surfaces contact and move past each other.
3. Friction between a roller and a surface is rolling friction.
4. Friction in machines is reduced by means of (*a*) roller or ball bearings, (*b*) smooth surfaces, (*c*) unlike surfaces moving over each other, and (*d*) lubrication.
5. Reducing the friction of a machine increases its efficiency.
6. Friction is useful to us in many ways.
7. Friction changes mechanical energy to heat energy.

EXPERIMENT 11. HOW MUCH DO ROLLERS REDUCE FRICTION? (P. 247). The apparatus and materials needed are:

Chalk or cigar box
Some metal or wooden rollers (round pencils will do)
Spring scale
Enough sand to make box and contents weigh several pounds
Long, smooth table top or other surface

a) Read the spring scale while it is being moved at a uniform rate of speed with the direction of the pull parallel to the table top.

b) Repeat as for part *a* and compare the results. Using about a dozen pencils arranged at intervals along the table top will make this part of the experiment work well. The force required for part *b* of the experiment will be much less than that for part *a* if the experiment is performed carefully and under good conditions.

SELF-TESTING EXERCISES (P. 253). 1. Answers will vary. Friction helps us walk and keeps us from slipping; it keeps gravity from pulling everything into low places; it changes mechanical energy to heat energy in striking matches. Friction also makes automobile brakes work and helps us hang onto things. The disadvantages of friction are that it reduces the efficiency of machines by changing mechanical energy to heat energy, which is lost, and that it makes machines, clothes, and many other things wear out from rubbing against other things.

2. The various ways of reducing friction include: (a) using rollers and ball bearings; (b) making surfaces very smooth; (c) lining bearing with Babbitt metal; (d) using jeweled bearings; (e) using oil or grease to separate moving parts. (Examples will vary.)

3. Rolling friction is usually much less than sliding friction. When surfaces slide past each other, uneven places on one surface move against uneven places on the other, causing much friction. But when one surface rolls over another, uneven places in one are lifted out of uneven places in the other, resulting in less friction.

PROBLEMS TO SOLVE (P. 254). 1. The temperature and speed at which the machines operate as well as the accessibility of the parts determine the kind of oil used in different kinds of machines.

2. The coefficient of friction is the ratio between the force required to move a body with uniform speed parallel to a surface and the force holding the body against the surface. (In Experiment 11 the coefficient of friction can be calculated by dividing the force needed to move the box by the weight of the box. The coefficient of friction for part *b* should be much smaller than that for part a.)

LOOKING BACK AT UNIT 4 (P. 254). 1. Refer to the unit graph on page 111. Answers to this exercise may include ideas indicated below:

What kinds of work does man do with machines? Many kinds listed in text. Few kinds of work in which machines are not used.

What kinds of resistance do we overcome with the use of machines? Gravity, inertia, adhesion or cohesion, friction, and elasticity.

In what ways do simple mechanical devices help us? (1) Multiply force. (2) Multiply distance and speed. (3) Change direction of force. (4) Store energy. (5) Transmit force.

How is work measured? By multiplying force used to move weight by distance force moves or by multiplying weight by distance it was moved by force. The unit is the foot-pound.

Do machines save work? Machines do not save work, but they do make work easier by multiplying force, by multiplying speed and distance, or by changing the direction of force. No machine is 100 percent efficient. You cannot get as much work out as you put in because there is always some friction.

Why are machines able to exert such large forces? Machines have a mechanical advantage. The greater the distance the force moves as compared with the distance the weight moves, the greater the mechanical advantage.

How do levers help us? By multiplying force, by multiplying speed and distance, and by changing the direction of force.

How do pulleys help us? (Same as levers.)

How do inclined planes help us? By multiplying force and changing its direction.

How does a wheel and axle helps us? (Same as inclined plane.)

How do screws help us do work? (Same as inclined plane.)

How do wedges help us do work? (Same as inclined plane.)

How do simple machines work together in complex machines? Simple machines working together in complex machines give a very great multiplication of force or of speed and distance. They also change the direction of force.

How can friction be reduced? By using ball bearings or rollers in place of sliding parts, by using Babbitt-lined bearings or jeweled bearings, by smoothing surfaces, by separating moving parts with oil or grease.

How is friction useful to us? It helps us walk and keep from slipping. It helps us hold onto things. It keeps gravity from pulling everything to low places. Brakes work by friction.

2. *Mechanical advantage:* amount of help in increasing force we get from a machine.

Block and tackle: combination of pulleys and rope used to lift heavy weights.

Pitch of a screw: distance between one ridge (or groove) and the next one.

Lever: bar working on a pivot or support called the fulcrum.

Fulcrum: pivot or support on which a lever turns.

Machine: device for making work easier.

Foot-pound: amount of work done when a force of one pound acts through a distance of one foot.

Jackscrew: device for greatly multiplying force. One turn of the handle through a big circle moves the weight a very small distance, thus giving a great mechanical advantage.

Work: force overcoming resistance and moving an object.

Jewel: bearing made of a very hard, smooth semi-precious stone, so that friction will be reduced.

Roller bearings: round, smooth rods that reduce friction.

Friction: rubbing of one thing against another, causing mechanical energy to change into heat.

ADDITIONAL EXERCISES (P. 254). 4. Such a system is shown in the right-hand drawing of Figure 223, page 236. The mechanical advantage of the system is 6.

5. The amount of work would be the same—500 foot-pounds (10 × 50).

6. 4625 foot-pounds (25 × 185).

8. Locomotive drive wheels, flywheel on gasoline or steam engine, piano key and hammer mechanism, skates, a spinning top, valves in hydraulic ram, wheel of a water turbine, pendulum of a clock.

9. Cream separator, governor on engine, centrifugal water pumps, rotary lawn sprinkler, certain types of washing machines, water and oil pumps in automobiles.

10. Air guns, clocks and watches, springs to shut doors, many mechanical toys, mechanical phonographs, knife blades in jackknives, window-shade roller, sugar tongs, springs to release brakes on automobiles and trains.

11. Pascal's Principle is the basis for the hydraulic press: *A force applied to an area of a fluid is transmitted undiminished in all directions to every equal area of a fluid.* This means that a pressure of one pound on a piston in a cylinder whose area is one inch can be transmitted to a piston in a cylinder whose area is 100 inches as a force of 100 pounds.

12. Dentist's chair, barber's chair, hydraulic brakes on automobiles, hydraulic elevators.

14. Force exerted on foot-pedal acts against a master piston in a

cylinder near front of car. Piston acts against oil in cylinder and in tubes from cylinder to brakes. Pressure on liquid acts on piston in each brake to push brake shoes apart against brake drum.

15. A differential pulley has two pulleys of different diameters fastened together at the top and a single movable pulley with an endless chain passing over the pulleys. As chain runs rapidly over two pulleys at top, single movable pulley moves upward very slowly but with great force.

PAMPHLET FOR UNIT 4

Standards Bureau Technologic Paper
No. 201. *Friction and Carrying Capacity of Ball and Roller Bearings.* 10c

VISUAL MATERIALS FOR UNIT 4

FILMSTRIPS

Society for Visual Education
"Mechanics I (Levers)" "Mechanics II (Inclined Plane)"
"Mechanics III (Pulleys—Wheel and Axle)"

MOTION PICTURES

Encyclopaedia Britannica Films
"Simple Machines"
"Energy and Its Transformations"

UNIT 5

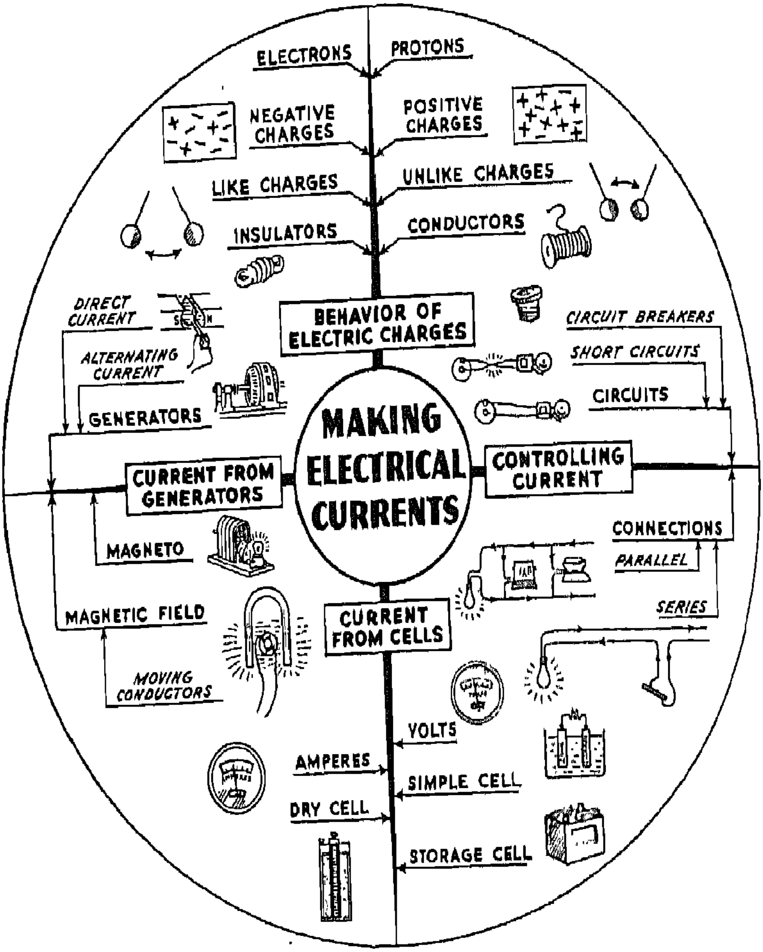
How Do We Make Electrical Currents?

FUNCTION AND SCOPE OF UNIT 5. One of the outstanding contributions of science to the convenience and comfort of the modern world has been made through the development of electrical devices. A study of the phenomena of electricity and the principles that are applied in its use contributes to the education of secondary-school pupils in two outstanding ways: (1) It increases their ability to use electrical devices intelligently, and (2) it helps them see more clearly the place of scientific developments and applications in the civilized world.

Because of the large number of electrical principles and the many applications with which pupils come in everyday contact, the study of electricity in this book has been divided into two natural divisions. The first division, Unit 5, includes the production of electrical currents together with the basic principles of electrical charges and electrical circuits. Thus pupils see the place of the two main kinds of current generators in the general scheme of things and think about electricity in terms of currents of electrons.

As in all the units of this book, the text material is intended to develop understanding of the basic principles that can be grasped by the average person and that make for an intelligent attitude toward the use of electricity but not to develop a wide knowledge of details or specific skill in repairing electrical devices. The understanding developed should indeed serve as a foundation for knowledge of details and of how to make repairs and adjustments, and many pupils will be interested in going further in these two directions, both by individual study and in practical-arts courses.

Lack of standard laboratory equipment should not prevent the doing of many experiments and the examination of much electrical equipment in homes, schools, automobiles, etc., while the unit is being studied.



FIG, 5. GRAPH OF THE SUBJECT MATTER OF UNIT 5

The understandings to be gained in this unit will be developed much more quickly if pupils have already studied chemical change, magnetism (*Science Problems, Book 1,* Units 5, 7), and energy and its transformations (Book 2, Unit 5). In case pupils have not had this background, the teacher should be ready to make such special explanations and supplementary assignments as are needed.

INTRODUCTORY EXERCISES (P. 258). 1. Answers vary a great deal but, to be complete, each should include examples of the use of electricity to produce light, heat, chemical change (storage batteries, electrolysis, electroplating), and force or movement (magnets and motors). A few pupils may see electrical currents as a means of transmitting energy from one place to another.

2. When things have electrical charges, these charges may be of two kinds, positive or negative. (The positive charge is the kind that appears on a glass rod rubbed with silk.)

*3. A wire is wrapped many times about a piece of iron or steel. Then an electrical current is sent through the coil of wire and the iron or steel becomes a magnet. (The whole device is called an electromagnet.)

*4. The space around a magnet in which its force is exerted. Shown by moving a small compass needle about a magnet or by sprinkling iron filings on a paper or glass plate placed over the magnet. The filings arrange themselves in a characteristic pattern especially when shaken slightly by tapping.

5. Two pieces of different metals (or carbon), a solution of a substance that acts chemically on one of the metals, and an insulating container for the solution. Metals are immersed in the solution without touching each other. When connected by a conductor, a current flows from one to the other.

6. Figure 271, page 292, of the text shows how such a connection can be made. For this exercise only one cell is needed.

7. How much electrical pressure is being exerted.

8. Coils of wire are turned rapidly in the field of a magnet. The ends of the wire in the coils are connected in some way to a circuit for using the current they produce.

9. Mainly from burning fuels and water power. Some wind is used. (Indirectly all come from the sun.)

10. Two different plates in a solution produce current as in any other cell. When current is sent backward, the chemical changes of the plates are reversed, and they are "rebuilt" so they can be used again and again.

LOOKING AHEAD TO UNIT 5 (P. 259). The mystery, interest, well-known history, and everyday use of electricity make its study very easy to introduce. The preview given in the textbook brings out the following ideas:

1. Electric current serves us as a wonderfully effective servant in many ways.
2. The use of electricity has come about within a short period of historical time.
3. The main principles of electricity can be easily learned and will help us understand how common things operate.
4. This unit includes some things about how electricity acts and how we make currents; a later unit will include the ways currents are used.

PROBLEM 1: HOW DO ELECTRICAL CHARGES BEHAVE? (P. 261)

The discussion of this problem is planned to develop a useful understanding of the behavior of the so-called static electrical charges and to relate them to current electricity. This understanding will illuminate the electrical phenomena commonly seen during winter months and assist in understanding a number of phases of current electricity. The main ideas brought out are:

1. When some substances are rubbed together, they begin to attract and repel other things in a peculiar manner; they have become electrically charged.
2. Two kinds of electrical charges are known, positive and negative.
3. Like charges repel each other and unlike charges attract each other.
4. Matter of all kinds seems to be made of two kinds of electrical particles—light, negative electrons and much heavier,

positive protons; ordinary, uncharged objects contain equal numbers of the two kinds.

5. The electrons seem to be able to move about; when more than usual get on an object, it has a negative charge; when more than usual leave it, it has a positive charge.

6. Attraction and repulsion can cause electrical charges to jump through the air and cause sparks and lightning.

7. Electrons move very easily through some materials, called electrical conductors, but with difficulty through other materials, called non-conductors or insulators.

8. An electric current is a stream of electrons flowing through a conductor.

EXPERIMENT 12. HOW DO FRICTIONAL CHARGES MAKE THINGS ACT? (P. 262). Apparatus and materials needed are:

Hard-rubber comb
Woolen cloth (coat sleeve may be used)
Small, dry paper wads (of tissue paper, if convenient)
Pith balls, if available
Silk thread, one foot
Some kind of support for ball on thread (Figure 246)
Piece of glass rod or glass tubing, 12 or 18 inches long
Silk cloth

For the most part pupils may be given a free hand to try out everything they can think of with the equipment suggested or with other things. Rubber balloons rubbed on woolen coats or sweaters do many surprising things such as sticking to a person's back or to the wall or standing apart when two are held by strings. Toy airplanes made of thin metal foil can be kept afloat by a charged wand or comb.

Part c should be done carefully and is probably more effective as a demonstration. Glass is more difficult to charge than rubber and so may not attract and repel so strongly. Heating the rod in a gas flame (and then cooling it before use) usually improves results.

SELF-TESTING EXERCISES (P. 266). 1. From the Greek *elektron*, the name for amber, which acted much like hard rubber when rubbed with cloth.

2. (*a*) Like charges repel each other; (*b*) unlike charges attract each other. Examples of each should vary widely.

3. Push apart. One way to demonstrate is to hang one charged comb up by a thread and bring another near it.

4. Carried out as in the preceding exercise. A bent wire with a hook at each end may be tied to the lower end of the thread so that a comb or rod can be supported in it after being charged.

SELF-TESTING EXERCISES (P. 269). 1. When an object contains equal numbers of the two kinds, they neutralize each other and show no charge at all.

2. (*a*) Gain electrons above the number of protons. (*b*) Lose electrons below the number of protons.

3. (*a*) Side of paper toward comb becomes positively charged because electrons have been repelled to farther side. (*b*) On touching comb many electrons are repelled from comb and attracted by paper. Whole paper thus becomes negatively charged and is repelled from negative comb. (See Figure 250, page 269.)

EXPERIMENT 13. HOW DOES STATIC ELECTRICITY ESCAPE FROM CHARGED BODIES? (P. 270). The articles needed for the experiment are:

Hard-rubber comb
Square of woolen cloth
  (or woolen clothing)
Small pieces of paper
Piece of bare wire

The main factor in the success of this experiment is the care with which all parts of the charged object are touched with the conductor. If carelessly done, the edges of the teeth of the comb will hold charges and give evidence of their presence.

EXPERIMENT 14. WHAT MATERIALS WILL CONDUCT ELECTRICITY? (P. 271). The apparatus and materials needed are:

Dry cell
Electric bell
Various materials to be tested, including metals and nonmetals
Two feet of insulated copper wire
Glass of distilled water
Tap water
Salt water

In case the ringing of the bell is undesirable, use two cells and connect a flashlight bulb in place of the bell. A shop teacher or radio repairman can easily provide a socket or solder wires to the contacts of a flashlight bulb. To test the conductivity of a liquid, insert the bare ends of the wire in the liquid.

Self-Testing Exercises (p. 274). 1. Before comb was touched with hand or wire, it had a charge. If not touched, charge remained for some time. When touched, it disappeared. The best explanation is that it moved away through the hand or metal or that the opposite kind of electricity moved in to neutralize charge on comb. (The former explanation is the accepted one in this case.)

2. Material through which electrons can move only with great difficulty, if at all. Glass, rubber, dry wood, cotton, silk, porcelain are non-conductors.

3. Through conductor electrons can move easily. Common metals and certain kinds of solutions are good conductors.

4. Damp air is a fair conductor, while dry air is a non-conductor.

5. Stream of electrons flowing through a conductor.

6. Flashes of light caused by great charges of electricity leaping from cloud to cloud or from cloud to earth. Sudden expansion and contraction of air during passage of electricity causes thunder.

7. (a) Hairs (all charged alike by rubbing on comb) repelled one another.

b) Comb had charge opposite to that of hair and so attracted it.

c) Moisture probably allowed both comb and hair to conduct electrical charges to body. Moisture also makes hairs stick together.

d) Lint was probably cotton or linen. It received a charge different from that on woolen cloth and so was attracted.

Problems to Solve (p. 275). 1. Tires of truck running on road charge truck with electricity. Chain is supposed to allow charge to escape to ground and prevent sparks that might set fire to vapor from gasoline. (The rubber tires insulate truck from ground. Recent experiments have shown that chain is really not very effective because the road surface is also non-conducting.)

2. Static electrical charges may leap across gaps from one object to another. When they do this, spark is produced which will ignite inflammable vapors. Many dangerous fires and explosions have been caused in this way.

3. Behavior of either end of arrow is same as that of paper (or pith ball) in Figure 250, page 269. See answer to Self-Testing Exercise 3, page 269.

4. Tin-foil arrow may or may not show attraction and repulsion. Its behavior depends on whether charges can escape through needle and on how large a charge is produced on charged object used for experiment.

5. Each sheet gets an electric charge in passing through printing press. Pile of paper soon has a high charge, and a sheet approaching pile with similar charge is strongly repelled.

6. Pith balls stand apart from each other and fly away from charged object because all three have same kind of charge and so repel each other.

7. Electrons will move from negative screw to positive screw. Only negative electrons are free to move, and they push or repel each other from screw on which the more of them have gathered.

NOTE: Pupils may encounter here what appears to be a disagreement with other readings on electricity. Before the nature of the current was known, it was customary to speak of a current flowing through a wire from the positive to the negative terminal. In this text the statements very carefully refer to the actual movement of the electrons, which are now known to go from the negative to the positive.

8. Woolen cloth rubbing on varnish of chair gave body a charge. When cloth remained in contact with varnish, charges on cloth and varnish neutralized each other. The facts given could be explained by the man's shoes rubbing or touching a woolen carpet or other floor covering that would produce a charge on his body.

PROBLEM 2: HOW DO WE CONTROL ELECTRICAL CURRENT? (P. 276)

Essential to an understanding of the use of electric current is a mental picture of a circuit, a continuous path through which electrons can pass from the device that makes them flow to the device that uses them and back again. Common devices used in managing currents to get the desired results should also be understood. Study of Problem 2 should result in the attainment of these ends. Specifically stated, the main ideas to be gained are:

1. Any arrangement for using electric current requires at least the following parts connected in what is known as a circuit: (*a*) something to make the electrons flow, (*b*) a good conductor arranged in a complete path for the electrons, (*c*) one or more devices to start, stop, or regulate the current, and (*d*) something to use the current.
2. Every electric current encounters friction, or resistance, and produces heat because of this electrical resistance.
3. Circuits in houses include a fuse or other device which will stop the current if it becomes large enough to heat the wires dangerously hot.
4. All wires in house circuits should be carefully insulated and protected from damage to the insulation.
5. When two devices are to be connected in the same circuit, they may be connected in either of two ways: (a) so that all the current will go through both or (*b*) so that part of the current will go through each one.
6. Whenever it has an opportunity, electric current from a generator will return to the generator without passing through a lamp or other useful device; when this happens, there is a "short circuit" with much current flowing, and wires are apt to be overheated.
7. Switches and push-buttons open and close gaps in a circuit to stop and start the current.

EXPERIMENT 15. HOW DO WE CONTROL ELECTRICAL CURRENT TO RING A BELL? (P. 277). Apparatus and materials are:

Dry cell
Push-button or switch
Bell (or buzzer or small bulb)
Two feet of insulated wire
Pair of pliers
Screw driver

Pupils who have never had the experience of connecting and operating an electrical device should be allowed to carry out this experiment individually. Some of the advantages that can be stated for an electric bell over other kinds are: (a) To ring it requires only energy enough to push the button. (*b*) The bell may be placed far from the location of the button, and yet no string or rope needs to move between the two places.

Legend for Figure 264 (p. 283). Switch is shown on.

Self-Testing Exercises (p. 284). 1. (*a*) Something to make electrons flow, (*b*) a good conductor arranged in complete path for electrons, (*c*) one or more devices to start, stop, or regulate current, and (*d*) some device to make use of current. Diagram should be some representation of essential connections shown in Figure 257, page 277.

2. Through one wire electrons go to device, and through other wire they return to part that makes them flow.

3. To keep wires in house from carrying too much electric current and becoming too hot. When fuses "blow," it is because too much current has flowed through them and has caused a soft metal wire to melt and fall apart.

4. To keep them from touching each other, a person, or some other conductor. This prevents damage from current's going where it should not go.

5. Short circuit occurs when great quantity of electric current goes back to generator without going through any useful device. This sometimes happens when two wires touch each other or when piece of metal is put in where lamp or other device should be connected. Under such circumstances there are usually lots of sparks and heat for a moment where the unusual contact is made. Then fuse in that circuit "blows out," and circuit cannot be used until trouble is located.

6. (a) When devices are connected in parallel, part of current goes through each device. Figure 263, page 282, shows this plan. b) When devices are connected in series, all current goes through each device in series. See Figure 264, page 283.

7. Diagram should show some arrangement similar to that in Figure 264, page 283.

Problems to Solve (p. 284). 1. Fuses are in series with lights.

2. See Figure 6 at top of next page. F represents fuses, and S switches. Unmarked circles are light bulbs.

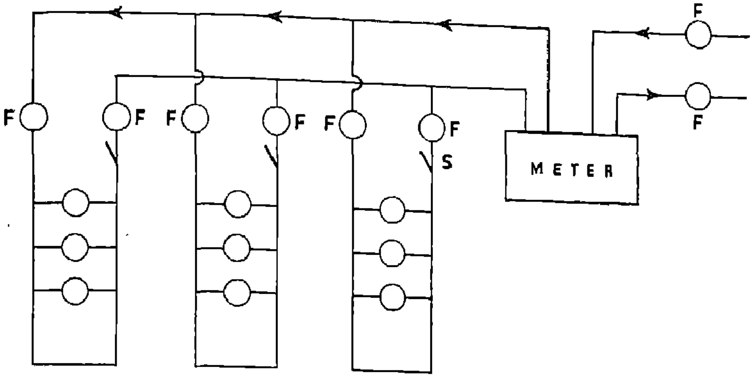


FIG. 6

5. Numbers indicate amount of electricity that fuses will allow to pass through without melting. Amount is measured in units called amperes. Thus a 5 on a fuse shows that it will carry 5 amperes of current.

6. When working with electric wiring in a house, main switch should be opened so that wires are disconnected from generator; thus there will be no danger of being shocked.

7. With a coin in place of a fuse amount of current that can get through is very great. In case of short circuit or overload, regular house wires may become overheated and start a fire.

8. When one light filament "burns out", all lights in the string or series go out. Advantages are that shorter and less expensive filament can be used in bulbs and that there is less danger of shocks or fires from poorly insulated wires along the string.

9. The real button should be compared with Figure 258, page 278.

PROBLEM 3: HOW DO WE USE CHEMICAL CHANGE TO MAKE ELECTRICAL CURRENT? (P. 285)

This problem deals with the information the average person should have about electrical "batteries," including dry cells and storage batteries. Pupils are always interested in making cells but should be held for an understanding of the principles common to all cells. The main ideas of the problem are:

1. Generation of current by means of chemical action in a cell requires two different kinds of metal plates (one may be carbon) and a solution of a chemical that will cause a chemical change in one of the plates; all electrical cells (batteries) provide these parts.

2. One plate of a cell is always used up in creating electric current; the chemical energy of this plate is transformed into the energy of the electric current.

3. A dry cell is not really dry, but contains a moist paste sealed inside the zinc can that forms one of the plates, or electrodes.

4. A storage battery is an electric cell in which the plate, destroyed by chemical action in producing a current, can be rebuilt by sending a current in the opposite direction.

5. The storage battery does not store electricity; it stores chemical energy that is produced while it is being charged.

EXPERIMENT 16. HOW CAN YOU MAKE A SIMPLE CELL? (P. 286). The apparatus and materials needed are:

Sensitive magnetic compass
Shallow cardboard or wooden box just large enough to hold compass (Fig. 266)
Five feet of insulated copper wire
Two strips of copper 1 × 5 in.
Strip of zinc (1 × 5 in.) and if possible a number of similar plates of different metals
30 cc. concentrated sulphuric acid
300 cc. water (or 350 cc. dilute sulphuric acid)
Hammer
Small nail
Two glass beakers (or two tumblers) and one large beaker for diluting acid
Wooden block (to lay strips on while making holes)
Solutions of vinegar, table salt, ammonium chloride, and sugar (all in distilled water)

In using the home-made galvanometer, be sure that the needle is free and parallel to the coils of wire wrapped around it. Nothing should happen when one copper strip is lowered into the solution. If all connections are good, the compass needle should swing violently to right or left when the zinc strip goes in. Two similar plates should show no current. Any combination of two plates of different metals should show a noticeable current. Any of the chemicals named except sugar solution should produce a noticeable amount of current. The sugar solution does not react with any metals and so produces no current.

EXPERIMENT 17. HOW IS A DRY CELL CONSTRUCTED? (P. 290). The apparatus and materials needed are:

Worn-out dry cell	Hammer
Large paper	Cold chisel or screw driver

If large dry cells are not available, old flashlight "batteries" are quite satisfactory for this experiment. The parts of the cells (zinc and carbon) can be used for simple cells.

SELF-TESTING EXERCISES (P. 293). 1. Two plates of different metals (one may be carbon); solution of chemical that will act on one plate; insulating container of some kind.

2. Zinc of such cell received more electrons and thus negative charge.

3. In simple cell, zinc and sulphuric acid change. In dry cell, zinc, ammonium chloride, and manganese dioxide change.

4. Yes. Materials named will make current flow because there are two different metals and an active chemical solution.

5. (a) Dry cells are connected in series when outside terminal of one is connected to middle terminal of the next and so on.
b) This arrangement gives four times as much electrical pressure as one dry cell.

6. Battery is made of two or more cells.

PROBLEMS TO SOLVE (P. 294). 1. Positive connection is in center of top. Binding post at edge is fastened to zinc. Zinc is used up and becomes negative when cell is used.

2. Because making of current to operate bulb uses up zinc in battery. When holes come in zinc, cells dry out and become useless.

3. No. Dry cell contains moist paste of ammonium chloride and other things. When it becomes really dry, it ceases to give a current.

4. Dry cells are connected in parallel when all outside terminals are connected together and all middle terminals are connected

together. This arrangement is used when very large amount of current is needed at pressure no greater than that produced by one cell.

EXPERIMENT 18. HOW CAN YOU MAKE A SIMPLE STORAGE CELL? (P. 295). The apparatus and materials needed are:

Glass tumbler (or ½ pint jar)
80 cc. of concentrated sulphuric acid
240 cc. of water (or 320 cc. of diluted acid, 1:3)
Two lead plates at least 1x5 in.
Electric bell
Six pieces of insulated wire each 1 foot long
Three dry cells

No difficulty should be found in doing this experiment successfully. Pupils must be watched to prevent carelessness with the acid, which is concentrated enough to "eat" holes in clothing.

a) Bell does not ring because plates are alike and no current can be generated.

b) Bubbles may usually be seen rising from lead plates while current is passing through solution. One plate gets brownish coating; other takes on fresher lead color. Colors indicate that plates are now different from each other.

SELF-TESTING EXERCISES (P. 300). 1. Simple storage cell has same essential parts as any simple cell; two different plates and solution that will act on one of plates. It is different in that plates are not completely destroyed and material that makes current can be reformed by sending current through in opposite direction.

2. Chemical energy.

3. Large flashlights usually hold two or three cells.

4. Automobile storage battery is always ready to supply current for spark coil, lights, starter, or other devices whether motor is running or not. When motor is running, current is sent through battery to restore it so that it can continue to supply current. Dry cells would soon "wear out" and have to be replaced.

5. Battery liquid causes hydrometer (battery tester) to give a reading different from when it is discharged.

6. Tap water usually contains impurities that would injure storage battery and shorten its life.

7. More dry cells than lead storage cells because each one produces a pressure of 1.5 volts, while a lead storage cell produces a pressure of 2 volts.

Problems to Solve (p. 301). 1. (a) Batteries are usually lighter and smaller than generators. They can be carried around without having long connecting wires.
b) Generator must be turned all the time it is supplying current. This is often inconvenient.

2. Paper covers insulate zinc container from metal objects and other conductors and thus keep electric current from being wasted.

3. Zinc plate does not really dissolve. Zinc gradually changes into another substance, zinc sulphate, which does dissolve.

4. Main advantage of storage battery is that it can be renewed by sending electricity through it. Usually, too, storage batteries can give out more current, although this is not necessarily true. Storage batteries have disadvantages of being quite heavy and of containing a corrosive liquid that spills out when battery is turned upside down.

5. The experiment described produces a distinct taste.

6. The cell described will produce enough current to register on homemade galvanometer (Experiment 16) or to taste as in preceding problem.

7. In almost any community a battery-service man will be found willing to give information to one or two pupils who will report to the class.

PROBLEM 4: HOW DO WE USE MECHANICAL ENERGY TO MAKE ELECTRICAL CURRENT? (P. 301)

A generator, very mysterious to the uninstructed, seems a comparatively simple machine to one who knows the principle on which it operates, and the principle is easily demonstrated and learned, as shown by the discussion of this problem. However, some familiarity with magnetism is needed before entering into the principle of the generator. The main ideas are:

1. Whenever a conductor moves across the lines of force in a magnetic field, a current of electrons tends to flow along the conductor.

2. Generators are arranged to produce a very strong magnetic field and to move many wires rapidly through this field; the currents thus produced are led out through wires to do useful work.

EXPERIMENT 19. HOW CAN YOU MAKE ELECTRIC CURRENT WITH A MAGNET AND COIL? (P. 303). Apparatus and materials are:

Galvanometer
Two permanent magnets
Coil of about 100 turns of small insulated wire (see part a.)

b) The galvanometer needle should swing in one direction when the magnet is moved in and an equal distance in the other direction when it is moved out.

c) A current should be produced by movement of either coil or magnet.

d) Increasing the speed of movement should increase the amount of current and make the galvanometer needle swing farther.

e) Two magnets should also increase the amount of current over that produced by one.

EXPERIMENT 20. HOW CAN A COIL OF WIRE ACT LIKE AN ELECTRIC GENERATOR? (P. 305). Apparatus and materials are:

Wire coil used for Exp. 19
Steel knitting needle or stiff straight wire at least six inches long
Large horseshoe magnet or two bar magnets
Galvanometer

This experiment offers few difficulties. The needle of the galvanometer will swing first to one side and then to the other because the current reverses direction twice for each revolution of the coil. The coil could not be turned in one direction indefinitely because the connecting wires would be twisted.

SELF-TESTING EXERCISES (P. 309). 1. Wires in coil have been cut by "lines of force" of field about magnet. Coil or magnet has been moved.

2. The diagrams may vary a great deal and yet be satisfactory. The essentials are: one or more magnets with their field; a coil to turn in the magnetic field; wires to lead current out of coil.

3. Current generated by a given coil can be increased (a) by putting more wires on coil, (b) by making magnetic field stronger, and (c) by moving coil faster through field.

4. Pupils may describe coil and magnet used in Experiment 20. Commutator could be made by pushing wire through cork and putting strips of copper on it for commutator.

5. Alternating current.

6. Current passes from armature to outside circuit through slip rings and brushes that rub against them. This arrangement takes the place of the wires in Experiment 20.

7. Commutators change alternating current of a generator armature into direct current.

8. Generator changes kinetic energy into electrical energy.

9. Many kinds of places may be listed. The following are examples: (a) On an automobile for charging the storage battery. (*b*) On an airplane to produce current for spark plugs of motors. (c) In a steam power plant for lighting a city. (*d*) On a steam locomotive to give current for headlight and for lights in cab. (e) In telephone exchanges. (*f*) On steamships to light ships and drive propellers.

PROBLEMS TO SOLVE (P. 310). 1. Responses vary with pupils. Many pupils may need to be reminded of generators on stationary gasoline engines and on automobiles.

2. (a) Armature carries a great many coils of wire. (*b*) Field is created by electromagnets with many loops of wire around them and pieces of iron to concentrate field. (c) Armature turns very rapidly.

4. If generator had no insulating material, current could not be controlled and led out of machine. Its fields would be much weaker even if current to form them could be forced to travel in circuits about "magnets."

5. (a) Speed up generator; put more wires around field magnets or send more current through them; and (*b*) put more coils of wire around armature.

6. Generator sends out electrical energy. It uses kinetic energy

to make electrical energy, that is, work must be done; force must overcome resistance to make new form of energy. Thus we see that generator would turn hardest when it is generating large current. (An experiment with a magneto or other hand-turned generator will verify this conclusion.)

7. Generators with electromagnets can be made to produce larger currents than those with permanent magnets (magnetos) because electromagnets can be made stronger than permanent magnets.

8. (*a*) Bicycles need to be light; storage batteries are relatively heavy. (*b*) Bicycles are frequently turned on their side and upset. This would spill the liquid from most storage batteries. (*c*) Bicycle lights and horn use little current and this can be satisfactorily supplied from dry cells.

9. From information in answer to Problem 6 it is evident that generator has ceased to generate current either because of some defect in generator or because circuit has been broken.

LOOKING BACK AT UNIT 5 (P. 311). 1. The ideas included by the pupils may be checked against the ideas stated in this *Guidebook* for each problem, pages 132, 137, 140, 143. Each answer must, of course, be judged for its value. Pupils can hardly be expected to state each of the ideas listed for every problem.

2. *Ammeter:* device for measuring size of an electric current.

Ampere: unit for measuring size of an electric current.

Armature: part of a generator in which a current is generated or the part of a motor that revolves.

Repel: to push away or to drive back.

Circuit: path through which an electric current flows from its source and back again.

Conductor: any material that conducts electricity well.

Electron: a negatively charged particle of electricity.

Fuse: in a circuit protects electrical devices and prevents fires by melting and breaking circuit when too large a current flows.

Field magnet: in motors and generators provides a magnetic field of force whose lines can be cut by wires.

Volt: unit for measuring the pressure of an electric current.

Galvanometer: device for detecting electric currents, measuring their size, and indicating their direction.

Generator: device for changing mechanical energy into electrical energy.

Short circuit: occurs when an electric current takes a shorter path back to its source, causing a very large current to flow.

Insulator: any material that will not conduct electricity well.

Electrical current: a stream of electrons flowing through a conductor.

Positive charge: charge a body receives when electrons are removed from it.

Series connections: connections in which electric current from source flows through each device on its way back to source.

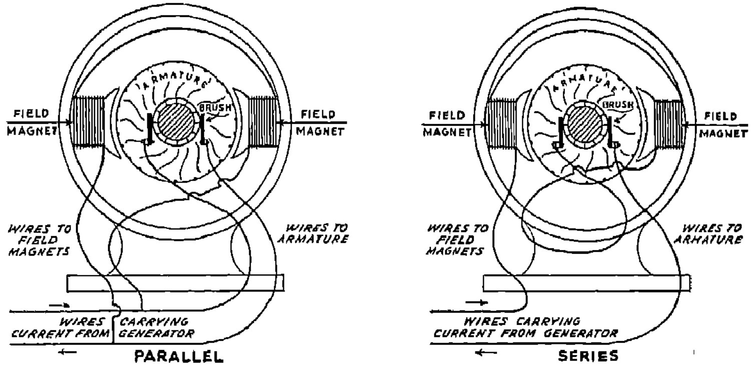
Alternating current: flows first one way and then the other, usually changing direction many times each second.

Storage battery: a device that can change electrical energy to chemical energy and then change chemical energy back to electrical.

Parallel connections: connections in which some of electric current flows through each device on its way back to source.

ADDITIONAL EXERCISES (P. 311). 1. Wire can be moved endwise or along lines of force in magnetic field without causing electrons to flow. In either of these two ways wire does not move across any "lines of force."

2. Two possible connections are shown in Fig. 7.



PARALLEL SERIES

FIG. 7

3. Field magnets require direct current to operate effectively.

4. In this type of galvanometer there is small coil attached to pointer and suspended between poles of permanent magnet. This coil acts as little motor and pulls against small spring. More current there is flowing through coil, farther coil will turn.

5. Small wire has more resistance than large wire. This can be seen by amount of current that can get through under certain pressure and by fact that small wire heats more than large one when both are carrying same current.

7. Main storage batteries of submarines are used to drive submarine when submerged and are charged by internal-combustion engines when submarine is at surface.

8. (a) Generators produce large quantities of current more cheaply; are not used up to produce current; can produce either alternating or direct current; contain nothing to spill or dry out. b) Cells contain own energy supply (do not need to be turned); are light and effective in small sizes; do not need oiling or adjustment until used up.

9. One possible arrangement is shown in Figure 8.

10. Better plan is to connect bells in parallel as shown in Figure 9. Additional cells may need to be added to battery unless transformer is used.

11. One arrangement is shown in Figure 10.

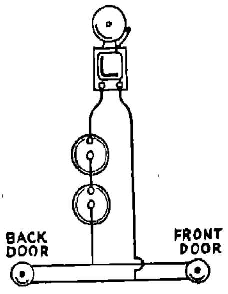


FIG. 8

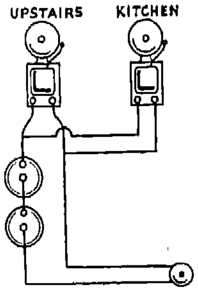


FIG. 9

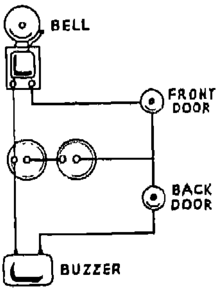


FIG. 10

12. (a) No moving parts connect engine with driving device; connecting cables may be almost any shape or length; easy speed

control and reversal. (*b*) Cost of generators and motors; space for generators and motors.

13. When coil is rotated, wires of coil cut across earth's magnetic field and thus generate a current.

14. Positive plate will attract negative particles and repel positive particles. Negative plate will do just the opposite. Thus negative particles will gather around positive plate and positive particles around negative plate. Way in which charged bodies act is in accordance with rule of charges, "Like charges repel; unlike charges attract."

17. When strips or wires of two different metals are joined together in an electric circuit and one joint is made warmer than the other, a current flows. This arrangement is a thermocouple.

PAMPHLET FOR UNIT 5

Federal Security Agency
  Modern World at Work. No. 1. *Electricity*. 15c

VISUAL MATERIALS FOR UNIT 5

Filmstrips

Society for Visual Education
  "Electricity"   "Magnetism"

Motion Pictures

Encyclopaedia Britannica Films
  "Chemical Effects of Electricity"
  "Heat and Light from Electricity"
  "Magnetic Effects of Electricity"

UNIT 6

How Do We Use Sound?

FUNCTION AND SCOPE OF UNIT 6. This unit serves to acquaint pupils with that form of energy known as sound. The importance of sound in our daily lives can hardly be overestimated, for it is one of the two principal natural means of communication. (The other, of course, is light, which is taken up in Unit 7.) Electrical devices, such as the telegraph, telephone, and radio, have greatly extended the range of sound; but to understand the operation of these devices, sound itself should first be understood. Accordingly, the electrical transmission of sound has been placed in Unit 8 (Using Electricity).

The first two problems of this unit explain the nature and elementary characteristics of sound, including the cause of sounds, their means of transmission, their speed in different materials, and the differences between sounds. Problem 3 deals with the production of musical sounds by the three groups of musical instruments. The next problem explains hearing in terms of sympathetic vibrations and the structure of the ear. (In Unit 8, sympathetic vibrations are again used to explain tuning a radio set.) Also, health practices with regard to care of the ears are discussed briefly. Problem 5 takes up the recording and reproduction of sound waves by means of the phonograph. The unit concludes with a practical problem on the control of sound and points out some of the ways of making sounds louder, preventing echoes, and reducing noise.

In Unit 6 pupils are introduced to the transmission of energy by waves, a concept used again in the two units that follow. Since it is usually difficult for pupils to grasp the idea that energy can be transmitted without the readily discernible movement of matter, wave transmission is first developed at the molecular level of sound. If wave length and frequency are explained at this level, their extension to the visible spectrum of light and the transmission of energy by radio and television will be easier.

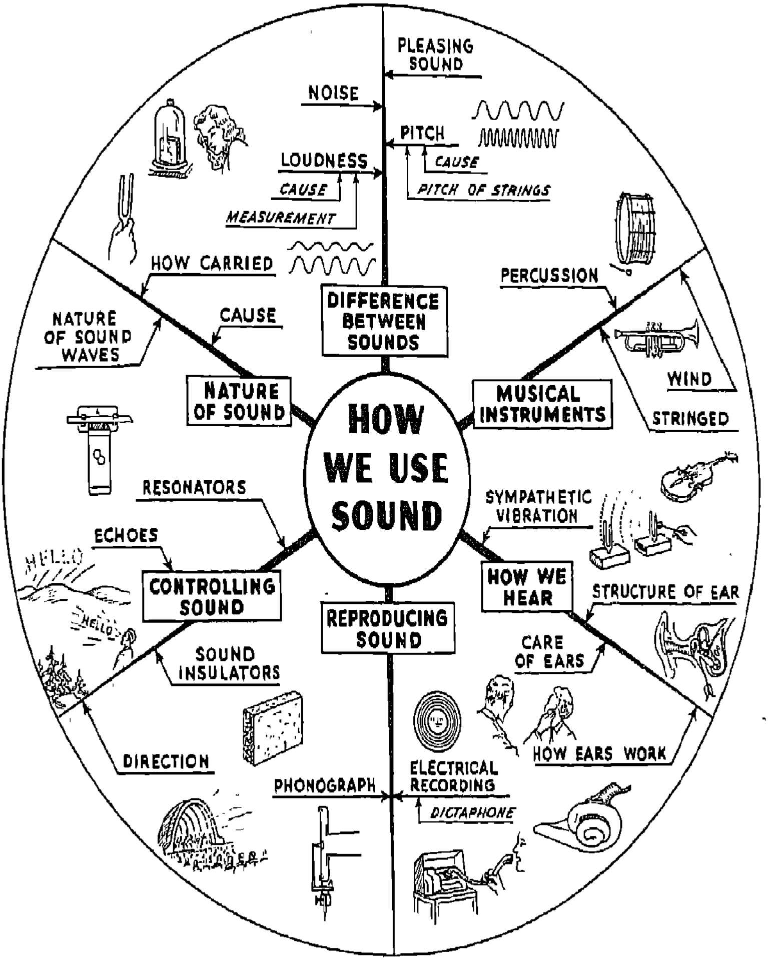


FIG. 11. GRAPH OF THE SUBJECT MATTER OF UNIT 6

INTRODUCTORY EXERCISES (P. 314). 1. Answers are individual. Ultimate cause of all sounds will be vibrating body.

2. Yes (in most cases). Ears detect direction.

3. By means of waves passing through air from bell to ear. Waves consist of alternate condensations and rarefactions of air molecules moving back and forth a tiny distance along lines in which sound is traveling.

4. No. Light travels much faster than sound (186,000 miles per second for light; about 1100 feet per second for sound). Smoke seen before report of gun is heard.

5. Pleasant sounds are made by regular sound waves, while annoying sounds are made by irregular sound waves.

6. To produce sounds of different pitch (highness or lowness). Long, thick strings produce low sounds. Short, thin strings produce high sounds.

7. Yes (for most pupils). Each instrument has its own quality of sound because it produces its own set of overtones.

8. Air from lungs makes vocal cords stretched over larynx, or voice-box vibrate, causing certain sounds according to how tightly or loosely vocal cords are stretched. Lips, tongue, teeth, and nasal cavity also help in making different sounds.

9. Outer ear collects sound waves. Ear drum vibrates when struck by sound waves, causing bones of middle ear to vibrate. Liquid in cochlea receives vibrations, and spiral membrane of cochlea vibrates. Nerves attached to membrane carry messages to brain where they are interpreted.

10. Reflection of sound waves from large surface at least fifty-five feet away.

LOOKING AHEAD TO UNIT 6 (P. 315). This section points out the importance of sound in our lives and also raises some of the questions which the unit will answer. It will be interesting to have pupils list the kinds of sounds they have heard during the day, such as voices, bells, automobile horns, etc. Since pupils will probably have studied communication in their social science courses, questions concerning the use of sound as a means of communication may be asked to bring out the social significance.

PROBLEM 1: WHAT IS A SOUND? (P. 318)

The study of the nature of sound is placed first in this unit because this knowledge is essential to an understanding of its use and control. Prior text material on the molecular nature of matter (*Book 1*, Unit 3) has paved the way for the concept that sound is the result of the action of molecules.

The crucial spot in the problem is, of course, sub-problem 4, "What are sound waves?" Pupils should not leave the problem until they have thoroughly grasped the idea of alternate bands of compressed and spread-out molecules pushing each other back and forth and thus passing the energy of the original vibrating body on or out through space. Pupils should clearly understand, however, that the molecules themselves move only through a relatively short distance. The main ideas are:

1. Sound waves are alike in one respect: They are all produced by something that is vibrating.
2. The sound of one's voice is produced by the vibration of vocal cords.
3. The kinds of sounds produced by the voice are regulated by making the vocal cords tighter or looser and by changes in the position of lips and tongue.
4. Sound is carried by solids, liquids, and gases.
5. The speed of sound varies in different kinds of materials.
6. Sound waves travel as a series of compressions and rarefactions—as wave motion.
7. Sound waves usually move outward in all directions from the disturbance causing them. Because they are constantly spreading over a larger area, sounds become fainter with distance.

EXPERIMENT 21. WHAT CAUSES SOUND? (P. 318). Apparatus and materials needed are:

Drum
Fine pieces of cork
Rubber stopper, one-holed, fitted with wooden or metal rod
Tuning-fork
Stiff bristle or paper triangle, 1 inch long
Piece of window glass
Candle
Wax

SELF-TESTING EXERCISES (P. 323). 1. *All sound is produced by vibrating bodies.* An object may vibrate too rapidly or too slowly to be perceived by ear.

2. Answers will vary. Pupils have used musical instruments, twanged rubber bands, etc.

3. Cords are drawn to each side as one breathes.

4. Messages from brain pass over nerves to muscles that regulate tightness of vocal cords. Muscles pull on cords. Air is forced out of lungs, making the cords vibrate. Messages from brain pass over nerves to tongue, jaws, and lips to regulate shape of mouth cavity. Thus sounds are produced.

PROBLEMS TO SOLVE (P. 323). 1. Running or excitement makes a person breathe more rapidly. Cords are drawn back, making them difficult to control.

2. Responses will vary. Snapping stretched wire or tightly stretched rubber band. Bristle or triangular-shaped piece of paper attached by sealing wax will show that the strings vibrate.

EXPERIMENT 22. DO SOLID SUBSTANCES TRANSMIT SOUND? (P. 325). Apparatus and materials needed are:

Wooden table
Tuning-fork
Cigar box with one end removed
Long iron or steel rod

Students should have no difficulty in discovering that the sound waves originated by scratching on wood can be heard much more distinctly through the wood than through the air. Metal transmits sounds even better than wood.

EXPERIMENT 23. DO LIQUIDS TRANSMIT SOUND? (P. 326). Apparatus and materials needed are:

Tuning-fork
Large cork
Glass or beaker
Water
Cigar box with one end removed (Exp. 22)

The tuning-fork will set the water in the glass in vibration, and this vibration will reinforce that of the tuning-fork, making the sound louder.

SELF-TESTING EXERCISES (P. 327). 1. Pupils should state that alarm clock can be heard plainly if there is air in bell jar, but that it becomes much less distinct when air is nearly exhausted and cannot be heard in a vacuum, showing that sound does not travel in a vacuum. NOTE: The vacuum in the jar is only a partial vacuum.

2. Examples will vary. Hearing under water when stones are tapped together, hearing an approaching train by placing an ear near track, hearing persons in other rooms when doors are closed, etc.

PROBLEMS TO SOLVE (P. 327). 1. Answers will vary. An interesting experiment can be done with two baking-powder cans. Bore a hole in center of bottom of one can. Tie button on string and pass string about 10 feet long through hole. Do same with other can. Stretch string tightly and talk softly into one can, while other person holds other can to his ear. It is even possible to hear the ticking of a watch over this "telephone."

2. Fathometer is device to find out how deep water is. Vibrations sent out under water from ship are reflected from bottom of sea and picked up by microphone under water. Time between sending out vibrations and receiving them is noted. Depth figured from this.

SELF-TESTING EXERCISES (P. 329). 1. Solids.

2. 4.8 seconds in air ($5280 \div 1090 = 4.8+$).

PROBLEMS TO SOLVE (P. 329). 2. Stop watch will be necessary. Experiment can best be performed at night when flash of gun can plainly be seen. Longer the distance (assuming that sound may be heard) between source of sound and observer, the more accurate will be the determination.

3. Answers will vary. At 20° C. in iron, 3.1 miles per second. At 0° C. in lead, 4402 feet per second; pine wood, 10,230 feet per second; glass, 15,066 feet per second.

EXPERIMENT 24. HOW DO SOUND WAVES MOVE? (P. 331). The apparatus and materials needed are: spring from window-shade roller, weight, hook or other support.

This experiment is introduced to give concrete experience with longitudinal or compressional waves. Pupils tend to think of waves as if they were all of the type which appear on the surface of water or in a rope, one end of which is shaken vigorously. Since sound waves are rather intangible, the visible waves in a coiled spring are substituted. The chief difficulty in performing the experiment lies in the speed with which the waves travel up and down the spring. If two or three shade springs can be hooked together to make a single spring which reaches to the ceiling, the waves of compression can be more readily followed with the eye.

SELF-TESTING EXERCISES (P. 334). 1. Answers will vary. A correct answer will include the idea that a sound wave consists of a rarefaction and a condensation.

2. (a) Series of waves spread out from source. Molecules through which waves pass move only small distance.
b) Sound waves spread in all directions from source. Water waves spread only along surface of water. Sound waves move back and forth in direction waves are traveling. Water waves move up and down at right angles to direction waves are traveling.

3. You can hear a bell ringing in a bell jar containing air. Other examples may be given.

PROBLEM TO SOLVE (P. 334). Wave that comes back is similar to wave that is sent except that it is inverted and amplitude of its vibration is less; that is, rope does not move so far up and down as it vibrates.

PROBLEM 2: WHY DO SOUNDS DIFFER FROM ONE ANOTHER? (P. 334)

This problem covers the main characteristics of sound, namely, pleasantness (regularity), loudness (intensity), pitch (whether the sound is high or low), and quality. These will not be understood by the pupil unless he has thoroughly grasped the nature of sound waves, as discussed in Problem 1.

The brief discussion of decibels on pages 339-340 opens the way for class investigation of the important problem of sound control in buildings indicated in the last problem of the unit. Background material is also provided to explain how sounds are produced in musical instruments and why the different kinds of instruments produce different qualities of sound (Problem 3). The main ideas of this problem are:

1. Unpleasant sounds are made by irregular sound waves; pleasant sounds are made by regular sound waves.
2. The loudness of a sound depends upon how far the air molecules are moved back and forth by the vibrating body and the distance from the source of the sound.
3. The loudness of sound may be determined with a sound-level meter.
4. The number of vibrations per second is called the frequency of sound.
5. The frequency of a vibrating string depends on (*a*) the length of the string, (*b*) the tightness of the string, and (*c*) the weight of the string.
6. The pitch of a sound depends upon how fast its source is vibrating; the faster the rate of vibration (or the greater the frequency), the higher the pitch.
7. The quality of a voice, musical instrument, etc., is determined by the combination of sounds resulting from the original tone and its overtones.

SELF-TESTING EXERCISES (P. 337). 1. Pleasant sounds are made by regular sound waves; unpleasant sounds are made by irregular sound waves.

2. Pupil diagrams should be similar to Figures 307, 308, and 309, pages 336 and 337.

SELF-TESTING EXERCISES (P. 340). 1. Particles move back and forth a greater distance in loud sound than in soft sound.

2. Too loud sounds if continued are believed to be harmful.

3. Unit used to measure loudness of sounds.

PROBLEMS TO SOLVE (P. 340). 1. One-fourth as loud. (Loudness of sound varies inversely as the square of the distance from the source.)

2. Answers will vary. May include various musical instruments. Blowing, striking, etc., hard or gently, will determine loudness or softness of sound.

EXPERIMENT 25. WHAT DETERMINES THE PITCH OF A STRING OF A MUSICAL INSTRUMENT? (P. 341). Apparatus and materials needed are:

Rubber bands of various lengths and thicknesses

Piano

Musical instrument such as mandolin, guitar, or violin (or sonometer if obtainable)

a) The experiment should show that short, thin, tightly stretched bands have a higher pitch than long, thick, loosely stretched bands.

b) When the string is pressed down so that it is shortened, the pitch will be higher. When the string is tightened, the pitch will be higher. The pitch of a thin string is higher than that of a thick string vibrating at the same rate.

SELF-TESTING EXERCISES (P. 344). 1. Pitch of sound refers to how "high" or "low" the sound is. Pitch of sound is changed when rate of vibrating source is changed.

2. This can easily be shown by driving two rows of nails about six inches apart on a board. Rubber bands of different thicknesses and stretched to different degrees will show differences in pitch when made to vibrate.

PROBLEMS TO SOLVE (P. 344). 1. Instrument may be tuned by bringing each string in tune (that is, to same number of vibrations) with corresponding piano string, or higher strings may be tuned to lower ones by shortening lower string by pressing on it at appropriate point.

2. About 4.3 feet (1100 ÷ 256) for Middle C.

3. About .31 foot (1100 ÷ 3500).

4. Speed of sound in air increases about 2 feet per second for each degree centigrade rise in temperature.

5. Sound waves may reinforce or interfere with each other. When two notes are very nearly same pitch, at one point vibrations cancel each other, producing silence. This results in "beats."

EXPERIMENT 26. IN WHAT DIFFERENT WAYS MAY A STRING VIBRATE? (P. 345). Apparatus and materials needed are: coarse guitar or piano string, two upright supports.

No difficulty will be encountered in this experiment if directions are followed. It is advisable to use the thickest string available, since its vibrations will be easier to see.

SELF-TESTING EXERCISES (P. 346). 1. Different instruments produce sounds of different quality; that is, overtones of one are different from those of another.

2. Overtones are produced when string vibrates in parts as well as whole. Pupil sketches should be similar to Figure 315, page 345.

PROBLEMS TO SOLVE (P. 347). 2. Shorter string is vibrating. Therefore, pitch is higher than when whole string vibrates.

3. Smaller curves representing overtones are different for the two instruments.

PROBLEM 3: HOW DO MUSICAL INSTRUMENTS PRODUCE SOUND? (P. 347)

The prevalence of school bands and orchestras as well as the general interest in music makes this problem worth while for ninth-grade pupils. Almost any class will have its budding musicians who gladly will bring their instruments for demonstration to the other members of the group. The music teacher or band director may also be called upon to give a talk on musical instruments.

Problem 3 applies to the three groups of musical instruments the ideas brought out in the preceding problems. Percussion instruments require very little explanation, but stringed and wind instruments present a little more difficulty. Most of the problem is therefore devoted to them. The main ideas brought out are:

1. Percussion, stringed, and wind instruments are the three groups of musical instruments; wind instruments are further divided into wood-winds and brasses.

2. Surfaces and air spaces in contact with a vibrating body reinforce its sound.

3. Sounding surfaces and air spaces also change the quality of a musical instrument by affecting its overtones.

4. Some wind instruments are played by changing the length of a vibrating air column; a short column makes high-pitched sounds, and a long column makes low-pitched sounds.

5. In other wind instruments vibrating reeds also help produce sounds.

EXPERIMENT 27. WHAT EFFECT DO SOUNDING-BOARDS AND AIR SPACES HAVE ON THE SOUND FROM VIBRATING BODIES THAT TOUCH THEM? (P. 350). Apparatus and materials needed are:

Cigar box with top
Small nails
Glue
Tuning-fork
Rubber hammer (one-holed rubber stopper on wooden rod)

The sounding-board and air spaces provided are very similar in action to those of a violin or other stringed instrument. Pupils who play any of these instruments may bring them to class for demonstration to the others.

EXPERIMENT 28. HOW DO WIND INSTRUMENTS PRODUCE SOUNDS? (P. 352). Apparatus and materials needed are:

Eight test-tubes, small diameter
Test-tube rack or other holder
Water
Harmonica
Bugle or other brass wind instrument

a) After the apparatus has been set up, it is a good plan to let the pupils predict (not "guess") the results of this part of the experiment, giving the reasons for their predictions. In almost every class some pupils will think that the tubes with the least water in them will give the highest sounds and those with the most water in them the lowest sounds. They will consider the water, which is clearly visible, as the vibrating source of sound rather than the air column, which cannot be seen. These pupils are probably reasoning by analogy from stringed instruments in which the shorter strings give the higher sounds and the longer strings the lower sounds. In this experiment, however, the water merely acts as a "false bottom" for the test-tubes. If closed tubes of corresponding lengths were substituted for those with water in them, the same results would be obtained.

When part a has been finished, some doubts may still remain among those pupils whose predictions were wrong. These may be cleared up in several ways. One good way is to use two or three bottles of the same general shape but different sizes. Have the pupils blow across the "empty" bottles as before and note the results. Another way is to substitute some other liquid, such as mineral oil, for water and repeat the experiment.

To show that there is no essential difference between a vibrating air column and a vibrating solid or liquid column, suspend the test-tubes by strings from some support and then tap them with a rod. The tubes of water will act like the wooden bars of a xylophone. Those with the most water in them will produce the lowest sounds and those with the least water the highest sounds. The contradiction is more apparent than real. For, in general, the longer the vibrating column of material (solid, liquid, or gas), the lower will be the sound produced. (Of course the air column in the tubes vibrates when the tubes are tapped, but the pitch is largely determined by the frequency of vibration of the solid and liquid.)

b) and (*c*) Other wind instruments may well be brought to class for inspection and demonstration. In part *b* the reed mouthpiece of a clarinet or saxophone may be used with good results. A trombone is especially effective to supplement part c. Pupils can see the sliding part move in and out as they hear the pitch raised or lowered.

SELF-TESTING EXERCISES (P. 355). 1. Some of the instruments that may be mentioned are listed below:

Percussion	*Stringed*	*Wind*	
Bass drum	Violoncello	Clarinet	French horn
Kettle drum	Bass viol	Saxophone	Trumpet
Snare drum		Sousaphone	Trombone
Xylophone		Tuba	Bassoon

2. The completed table is given below.

INSTRUMENT	PART THAT PRODUCES SOUND	HOW PITCH OF SOUND IS CONTROLLED
Piano	Vibrating strings	Strings of different lengths and of different diameters produce sounds of different pitch.
Harp	Vibrating strings	Strings of different lengths and of different diameters produce sounds of different pitch. Tension of strings may be increased by pedals.
Violin	Vibrating strings	Strings of different diameters are stretched differently. May also be shortened by fingers.
Saxophone	Vibrating reed sets air column in vibration.	Valves are opened and closed to shorten and lengthen air column.
Trombone	Vibrating air column in tube	Sliding part is moved back and forth to shorten or lengthen air column.
Harmonica	Vibrating reeds	Reeds of different lengths produce sounds of different pitch.
Kettle drum	Vibrating drumhead	Different sizes produce sounds of different pitch. Also hand screws and foot pedals change tension of drumhead.

PROBLEMS TO SOLVE (P. 355). 1. Instruments include violins, violas, violoncellos, bass viols, clarinets, oboes, English horns, bassoons, piccolos, flutes, trumpets, trombones, tubas, alto horns, harp, kettle drums, bass drum, etc. Usual arrangement puts strings (except bass viols) at front, with wood-winds behind them, brasses and drums farther back, and bass viols at the rear. Individual arrangements vary somewhat.

2. Reeds of clarinet and saxophone are essentially the same, though there may be some difference in width. They produce different kinds of sounds because overtones are different. Clarinet usually has straight, slender wooden tube. Saxophone has curved, swelling metal tube. Differences in shape and materials cause different overtones.

PROBLEM 4: HOW DO WE HEAR? (P. 356)

Since oral communication depends upon hearing, it is necessary for the pupil to get some idea of how the human ear transmits sounds. No attempt is made to explain the interpretation of sound in the brain. Care of the ear is also included because ear infections are quite common in pupils of this age. The major concepts are as follows:

1. Sound waves from one body may make another body vibrate at the same frequency; they are said to be in sympathetic vibration.
2. The ear receives sound waves which are transmitted by the ear drum and by three small bones in the middle ear to the liquid of the cochlea, which contains a coiled tapering membrane. Different parts of this membrane vibrate in sympathy with sounds of different pitches. The vibrating part or parts disturb corresponding nerve fibers and send impulses to the brain.
3. Hearing devices use some method of amplifying sounds so that they may be transmitted to the membrane in the cochlea.
4. The ear is a delicate organ and must be protected from infection or injury.

EXPERIMENT 29. HOW CAN ONE SOUNDING BODY PRODUCE SOUND IN ANOTHER BODY? (P. 357). Apparatus and materials needed are:

Two cigar boxes with one end removed from each
Two tuning-forks that produce same number of vibrations per second
One tuning-fork that produces different number of vibrations per second
Tiny nails
Hammer

Since it has been shown that a vibrating object such as a bell, a stretched wire, or a tuning-fork does produce sound waves in the air, this experiment is inserted to show that these waves in the air can in turn cause other objects to vibrate if they are capable of vibrating at the same frequency. This idea is applied later in Unit 8 to "tuning" a radio receiver.

Self-Testing Exercises (p. 358). 1. Sympathetic vibrations are produced in object when it is struck with sound waves of same frequency of vibration as object itself.

2. Pictures on wall may vibrate when certain note on piano is struck. You can sing certain note into piano, and string of corresponding pitch will vibrate. Other examples may be given.

Self-Testing Exercises (p. 363). 1. Alike in that they consist of different strings or strands of different lengths and thicknesses. Different in that they are not stretched to produce a certain pitch.

2. Because strands in membrane of cochlea respond to different pitches of transmitted sound by sympathetic vibration.

3. (*a*) Sound waves strike ear drums and set them in vibration. (*b*) Sound waves travel inward through bones of middle ear and fluid of inner ear. (*c*) Certain part of membrane of cochlea is set to vibrating. (*d*) Nerve fibers connected with this part of membrane send messages to brain. (*e*) Messages are interpreted in brain as sounds.

4. To equalize air-pressure on the two sides of ear drum.

5. (*a*) Keep out of water that contains germs. (*b*) Wear ear stoppers for protection when swimming if necessary. (*c*) Avoid very loud noises close to your ears when possible. (*d*) Avoid blowing nose too hard. (*e*) Consult doctor when anything is wrong with your ears.

Problems to Solve (p. 363). 2. Refer to Figure 326, page 359. Note that balancing organs have three parts at approximately right angles to each other. They contain sensory structures which when stimulated inform us of the position of our body.

PROBLEM 5: HOW ARE SOUND WAVES REPRODUCED? (P. 363)

In the preceding problems of the unit the pupils have become acquainted with the nature, characteristics, production, and reception of sound waves. Problem 5 is devoted to the reproduction of sound waves by means of the phonograph. Most of the discussion and all of the experimentation are kept at the level of mechanical recording and playing because this is most easily understood. Although electrical recording and playing are now the better methods, they do not differ basically from the older mechanical methods. The main ideas of the problem are:

1. Sound waves may be recorded mechanically by making a diaphragm vibrate; the vibrating diaphragm causes a cutting needle to make curved grooves in a rotating disc.

2. Mechanical reproduction of sound waves on a phonograph record is just the reverse of mechanical recording; curved grooves on a rotating record cause the needle to vibrate; the vibrating needle makes the diaphragm vibrate and send out sound waves.

3. Electrical recording and reproduction of sound waves are fundamentally the same as the mechanical methods; they merely make possible more natural sound reproduction.

EXPERIMENT 30. HOW DOES A PHONOGRAPH RECORD PRODUCE VIBRATIONS? (P. 366). Apparatus and materials needed are:

Phonograph	Sewing-machine needle
Phonograph record	Small, stiff card

No difficulty will be encountered with this experiment. Pupils have a good opportunity to feel as well as hear sound waves and again notice how they may be reinforced.

SELF-TESTING EXERCISES (P. 367). 1. Voice or music makes air vibrate. Sound waves carrying vibrations reach diaphragm of recorder, causing it to vibrate. Vibration transmitted to sharp needle, which cuts wavy groove in soft wax plate that is rotating.

2. Because cutting needle vibrates back and forth with vibrating diaphragm.

3. Electric current used to transmit vibrations to cutting needle. Very high and very low notes are recorded. Sounds more natural. Improves quality of sound.

4. Wavy grooves in rotating record make needle vibrate. Needle transmits vibrations to diaphragm, which vibrates and sends out sound waves in air. In electrical phonographs, needle vibrations are changed to electrical waves, amplified by radio tubes and then go to loud speaker.

PROBLEMS TO SOLVE (P. 367). 2. Hill-and-dale recording is done by having cutting needle move up and down instead of back and forth. Used on early phonograph but given up because records must be heavier and thicker than usual ones. Now used for radio transcriptions of high fidelity.

PROBLEM 6: HOW DO WE CONTROL SOUND? (P. 368)

This problem serves to round out and conclude the unit on sound by discussing three practical problems in controlling it. The three sub-problems cover making sounds louder, preventing echoes, and reducing noise. Of course in a book of this scope the discussion must be kept at a non-technical level.

In designing auditoriums and theaters, a good deal of attention is now given to their acoustical properties. Pupils may wish to investigate the school auditorium to determine its acoustics (in a very elementary way, of course) and then make recommendations for improvement. A sounding-board on the stage or heavy curtains at the back of the auditorium will often make a surprising difference in ability of the audience to hear.

Pupils may also survey the school to reduce noise in classrooms, corridors, the school lunchroom, etc. Simply making pupils "noise conscious" should help reduce unnecessary noise in the school building. The main ideas brought out in the problem are:

1. Megaphones and band shells make sounds louder by sending the waves in the directions we wish them to go and preventing them from being scattered in all directions.

2. Resonators and sounding-boards make sounds louder by means of a reinforcing air column in sympathetic vibration with the vibrating source of sound.

3. Echoes are caused by the reflection of sound waves from a large surface; they may be controlled in buildings by proper design of rooms or by materials that absorb sound.

4. Noise reduces efficiency of workers, disturbs sleep, and causes unhealthy nervous tension; it may be lessened by reducing the number of causes of sound and by using materials and devices that absorb sound.

SELF-TESTING EXERCISES (P. 371). 1. Reflection of sound from large surface.

2. Make sounds blurred and hard to understand.

3. By planning shape and size of rooms; by using materials with soft, rough surfaces that absorb sounds.

4. By directing all sound waves in one direction and thus preventing them from scattering in all directions.

PROBLEMS TO SOLVE (P. 371). 1. If stopwatch is available, fairly accurate determination is possible. Make short, easily recognizable sound and start watch. Stop watch when sound is heard as echo. Multiply time in seconds by 1100 feet (distance sound travels in one second at ordinary temperatures) and divide by two to get distance from source to reflecting surface.

2. Acoustical engineering includes designing rooms for proper acoustical properties and correction of acoustical defects in existing rooms. Band shells are also designed by acoustical engineers.

SELF-TESTING EXERCISES (P. 373). 1. Noise cuts down workers' efficiency, disturbs sleep, and causes unhealthy nervous tension.

2. (a) Reduce causes of noise. Examples: rubber tires and heels, heavy carpets, etc.
b) Absorb noise after it is caused. Examples: mufflers, sound-insulating materials, etc.

3. Material (usually porous and flexible) that does not transmit sound. Examples: rock wool in walls, felt strips in auto bodies, rubber pads under typewriters, etc.

PROBLEMS TO SOLVE (P. 373). 1. Sound-insulating materials in walls, heavy curtains on walls, thick carpets, etc., are all used.

2. Many kinds of materials now on market. Most are soft and porous.

3. See answer to Problem to Solve 2, page 327. (Problem repeated here to bring out relationship with reflection as well as speed of sound.)

4. To insulate vibrating bell from metal plate, which would have carried vibrations out of bell jar.

LOOKING BACK AT UNIT 6 (P. 373). 1. See main ideas listed on pages 153, 157, 159, 163, 165, and 166.

3. *Acoustical engineer:* helps solve problems that arise in controlling sound.

Auditory nerve: nerve that transmits impulses from spiral membrane of cochlea to brain.

Cochlea: snail-shell-like structure that forms inner ear and is filled with liquid.

Echo: repetition of a sound caused by reflection of sound waves from large surface.

Larynx: voice-box; frame of cartilage in throat where vocal cords are.

Quality: characteristic of sound determined by its overtones.

Noise: unpleasant sound caused by irregular sound waves.

Overtone: higher tone produced when body vibrates in parts as well as whole.

Percussion instruments: instruments played by striking them; drums, xylophone, cymbals, etc.

Pitch: highness or lowness of sound; varies with frequency of vibration.

Reed: piece of wood or metal that vibrates to produce sound in some wind instruments.

Resonator: device to make sounds louder by means of sympathetic vibration.

Sound waves: series of rarefactions and condensations transmitted through materials by action of molecules in materials.

Sympathetic vibration: occurs when object is struck by sound waves that vibrate at same frequency as natural frequency of object.

Vocal cords: strands in larynx which vibrate and produce sound; can be made tighter or looser by muscles, thus changing sound.

ADDITIONAL EXERCISES (P. 373). 1. Air column in organ pipes.

2. No. Speed of sound is independent of pitch.

3. (a) Hand gathers up more sound waves and leads them to ear, making sound waves in ear stronger.

b) Hands act like megaphone, sending sound waves toward person instead of letting them scatter as much as usual.

4. Speeding up number of revolutions would increase pitch of music because pitch depends on frequency of vibrations. The more vibrations per second, the higher will be the pitch.

5. Sound waves are not allowed to spread in all directions and thus to diminish in intensity.

7. Cigar box used in Experiment 27 can be used here.

8. Helmholtz discovered cause of differences in quality of musical sounds.

9. Geophysical prospecting is somewhat similar to use of fathometer. Sound waves from explosion set off in earth travel down through rock layers until they strike dome or irregularity, where they are reflected back to surface and recorded by seismographs. From elapsed time and direction of reflected waves, structure of underlying rocks can be determined.

10. Doppler effect is observed when train or automobile approaches or goes away from us. As object approaches, pitch of bell or whistle or noise made by object seems to rise. As object recedes, pitch seems to fall.

BULLETINS AND PAMPHLETS FOR UNIT 6

Bell Telephone Laboratories, New York
  Information about sound and communication
Coast and Geodetic Special Publication
  No. 108. *Velocity of Sound in Sea Water.* 5c
Standards Circular
  No. 403. *Discussion of Some of the Principles of Acoustical Insulation.* 5c
Standards Research Paper
  No. 800. *Recent Sound-Transmission Measurements at National Bureau of Standards.* 5c

VISUAL MATERIALS FOR UNIT 6

FILMSTRIPS

Society for Visual Education
  "Sound" "How We Hear"

MOTION PICTURES

Encyclopaedia Britannica Films
  "Sound Waves and Their Sources"
  "Symphony Orchestra"
Ideal Pictures Corp.
  "Sound Waves and Their Sources"

UNIT 7

How Do We Use Light Energy?

FUNCTION AND SCOPE OF UNIT 7. This is the initial treatment of the topic of light in this series. Except for the concept of energy, the unit is independent of all prior material. The main intellectual objective of the unit, as presented, is to understand in an elementary way the nature, the properties, and the uses of light energy. To this end the text takes up the wave nature of light energy, reflection, refraction, illumination, artificial production of light, optical devices used in vision, the camera, and color.

From the standpoint of personal values the subject matter is of special importance in stressing the fundamentals of correct lighting and of the hygiene of the eye. Problem 3 and part of Problem 4 deal with these important considerations, and they should be given thorough treatment. Time permitting, the text discussion should be enriched by supplementary material on the care of the eyes. A local eye doctor may be available to speak to the class.

The effect of lenses on light and the nature of color are, of course, the "hard spots" of the unit. Fortunately, however, there is abundant opportunity for the pupils to have actual experiences with these aspects of the treatment. Lenses are commonplace and easily secured. Color is an everyday phenomenon. With such opportunity for actual experience and observation the difficulties of this material largely disappear, and the study of the phenomena becomes of great interest to the pupils.

INTRODUCTORY EXERCISES (P. 376). *1. Energy is something that makes matter move or change. Light is a kind of energy because it can cause carbon dioxide and water to change into sugar in green plants, because it changes camera films, and because it fades cloth, tans skin, etc.

2. Luminous object produces and sends out light. Non-luminous object merely reflects light from some luminous object.

3. Light. Experiences will vary but will probably mention seeing something happen at a distance before hearing sound.

4. (a) Mirror reflects most of light that falls on it. Light

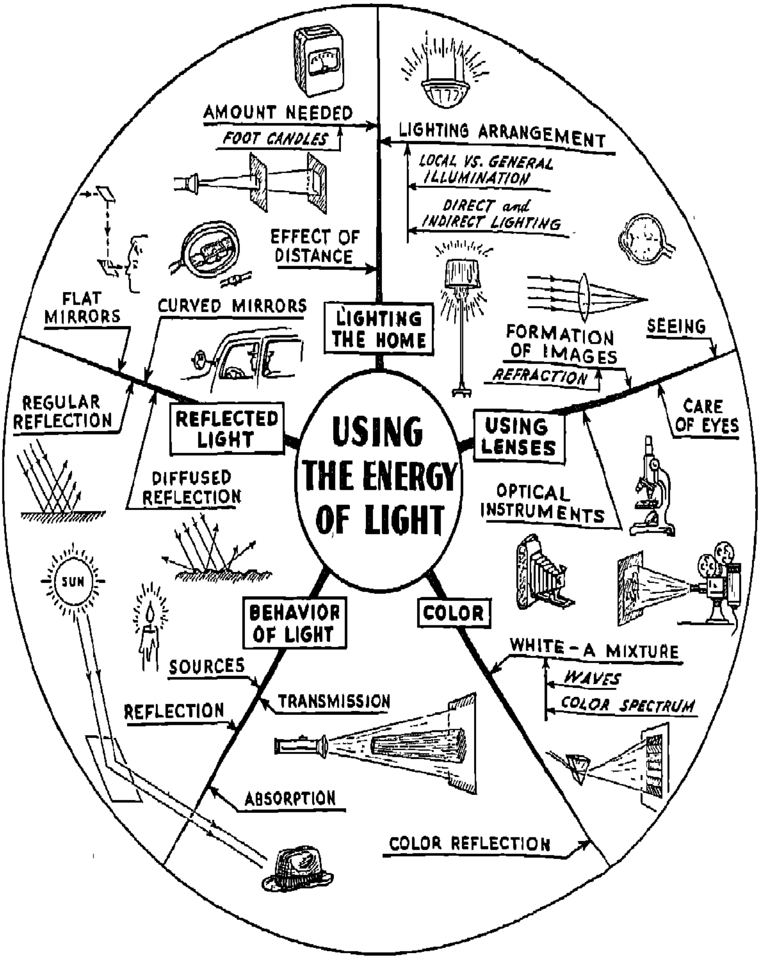


FIG. 12. GRAPH OF THE SUBJECT MATTER OF UNIT 7

regularly reflected in straight lines. Angle of reflection of light equals angle of incidence. Thus image of self can be seen in mirror. *b*) Curved mirror reflects light differently from flat mirror.

5. Parts of eye: lens, iris, retina, optic nerve; parts of camera: lens, iris diaphragm, film or plate. In both eye and camera, lens focuses inverted image on surface and amount of light entering is controlled by opening or closing iris or iris diaphragm. In eye, focusing is done by changing thickness of lens, while in camera, focus is brought about by moving lens nearer to, or farther from, plate or film. Light falling on retina of eye sends messages to brain by means of optic nerve. Light falling on camera film or plate causes chemical change in film or plate. (Other likenesses and differences may be mentioned.)

6. Spectacles, or eyeglasses, help people see better by means of lenses that correct defects of eye lens or shape of eyeball so that light rays can be brought to proper focus on retina.

7. White light of sun separated into seven colors of which it is composed by drops of water in air, which act like prism.

8. Red absorbs all colors of white light except red, which it reflects, thus making dress appear red.

9. Main instruments are telescopes (reflecting and refracting) and microscopes. Microscopes and refracting telescopes use convex lenses. Reflecting telescopes use concave mirrors.

LOOKING AHEAD TO UNIT 7 (P. 377). The introduction to this unit raises problems having to do with refraction, reflection, and color. The traffic device shown in Figure 338 is, of course, a series of prisms that bend the light rays to bring them within the vision of the driver approaching the top of the hill. It would be valuable, and a simple matter, to have a round beaker of water on the desk to give the pupils visual evidence of the problem suggested in paragraph three. Similarly, magnifying glasses and other lenses, mirrors, colored glass or colored light bulbs, and perhaps a prism will make vivid the nature and function of the unit.

The everyday experiences of the pupils provide so many examples of the problems of the unit that this introductory section, together with the Introductory Exercises, might easily be made to consume too much rather than too little time.

PROBLEM 1: HOW DOES LIGHT BEHAVE? (P. 380)

What light is (in terms of the wave theory) and how light travels are the major considerations in this problem. That light travels, that we see objects only when light travels from the object to our eyes, and that light is absorbed by some materials will probably be novel ideas to the majority of the pupils. Refraction is purposely delayed until a later problem in order not to introduce too many new concepts at once. The concepts presented are as follows:

1. Objects to be visible must be luminous or must reflect light from some luminous source.
2. When light strikes a material, the light may be reflected by the material, absorbed by it, or transmitted through it.
3. Light is a form of radiant energy; when it is absorbed by a material, it is changed to heat.
4. Light has certain properties that make it behave as it does:

a) It is capable of passing through space containing no matter.
b) It travels at the rate of 186,000 miles per second.
c) It travels in straight lines in a medium of the same density throughout.
d) It is sent out in all directions from a luminous source.

SELF-TESTING EXERCISES (P. 382). 1. Because no light is entering our eyes.

2. No. Luminous object supplies its own source of light. Objects may be illuminated by light from luminous source.

3. Because it reflects light to eyes from lamp or sun, both of which are luminous. Black print does not reflect light. Letters are visible because white paper around letters reflects light.

PROBLEM TO SOLVE (P. 382). No. It reflects light from sun. (Pupils may be referred to page 25 of *Science Problems, Book 2.*)

EXPERIMENT 31. WHAT BECOMES OF LIGHT THAT IS NOT REFLECTED FROM AN OPAQUE MATERIAL? (P. 384). Apparatus and materials needed are: lamp with opaque shade, white paper or cloth, dark or black cloth.

The difference in the amount of reflected light can best be observed by reflecting light on the face of someone near it.

Have the pupils look at the person's face and then do each part of the experiment.

Self-Testing Exercise (p. 385). Opaque materials absorb light, and none passes through. Translucent materials absorb some light but allow some light to pass through. Transparent materials absorb little light, and most of it passes through.

Self-Testing Exercises (p. 387). 1. Light has power of bringing about changes in matter, and it can be changed to other forms of energy. Also, other forms of energy can be changed into light.

2. (*a*) By photosynthesis light energy changed into stored chemical energy in sugar. (*b*) By absorption light energy changed to heat energy.

3. Absorbed light changed to heat.

Problems to Solve (p. 387). 1. Clear water is fairly transparent so that light from object passes through water. Muddy water contains opaque particles that absorb light from object; thus object cannot be seen.

2. In fog, much light is absorbed or reflected by particles of water, so that only some light passes through. Fog is translucent.

Experiment 32. In What Way Does Light Travel Away from an Object? (p. 389). Apparatus and materials needed are:

Three pieces of cardboard, tin, or wood, six inches square
Supports for pieces
Candle, electric lamp, or flashlight
Shears or saw

Directions for carrying out this experiment are sufficiently detailed. A candle supplies the best source of light, since it presents a relatively narrow source.

Self-Testing Exercises (p. 391). 1. Light travels much faster than sound.

2. Light does not pass through opaque materials, nor does it bend (while traveling in same medium).

3. Source of light, object to cut off light, background to reflect light not cut off.

Problems to Solve (p. 391). 1. 500 seconds (8⅓ minutes).

2. Find elapsed time. Compute distance light travels in one year and multiply elapsed time by this figure.

3. Place book between source of light and wall. To make shadow larger, bring book nearer source of light; to make shadow smaller, move book nearer wall. Source of light can also be moved.

4. Straight line can be drawn from top or bottom of shadow to top or bottom of object and then to source of light.

5. Toothpicks should be placed to show that light travels in all directions.

6. Most people are right-handed. Light should come over left shoulder to prevent formation of shadows of right hand on paper.

PROBLEM 2: HOW DO WE USE REFLECTED LIGHT? (P. 392)

This problem takes one aspect of the behavior of light, namely, reflection, and discusses it in detail because reflection and absorption are so basic to the commonest experiences with light. Thus, mirrors are given the attention of an entire subproblem. Furthermore, the concepts involved in reflection and absorption are fundamental to an understanding of the correct methods of lighting our homes, treated in the next problem. They are as follows:

1. When light is reflected, the angle of reflection is equal to the angle of incidence.
2. Light is regularly reflected when the whole beam is reflected together; surfaces that do this act as mirrors.
3. When the reflected light is scattered by the surface on which it falls, it is said to be diffused.
4. Materials differ greatly in their reflecting power.

EXPERIMENT 33. HOW IS LIGHT REFLECTED? (P. 392). Apparatus and materials needed for the experiment are:

Table
Large sheet of paper
Pencil
Mirror (metal if possible)
Pins
Protractor

Figure 350, page 393, will make clear the arrangement of the apparatus. The experiment should be repeated at least once with the position of the first pin changed. This will, of course, require that the position of the second pin be changed and the new angles formed be measured.

EXPERIMENT 34. HOW IS LIGHT REFLECTED FROM UNPOLISHED SURFACES? (P. 394). Apparatus and materials needed are:

Table
Dark cloth
Lamp
Opaque box or reflector
White cardboard, paper, or cloth
Mirror

When the white surface is used, the light should be dimly scattered over the whole ceiling. When the mirror is used, it will light only one spot on the ceiling. Call attention to the fact that the spot produced by the mirror is much lighter than the area lighted by diffusion from the white paper.

SELF-TESTING EXERCISES (P. 397). 1. Drawing should be similar to Figure 350, page 393, except that candle will replace pin. Eye must be placed so that angle of incidence and angle of reflection are equal.

2. Surface of mirror is polished, and light is regularly reflected (therefore concentrated). On the other hand, surface of paper is rough, and beam of light is scattered.

3. Some objects absorb more light than others and hence appear darker. Some objects reflect more light than others and hence appear brighter.

PROBLEMS TO SOLVE (P. 397). 1. Water fills up space between rough particles of pavement, making smooth surface that acts as mirror.

2. Too much light is reflected to eyes by paper.

EXPERIMENT 35. HOW CAN WE PROVE THAT THE IMAGE IN A MIRROR APPEARS AS FAR BACK IN THE MIRROR AS THE OBJECT IS IN FRONT OF THE MIRROR? (P. 398). Apparatus and materials needed are:

Sheet of clear glass
Support for glass
Two candles
Matches
Ruler or yardstick

When the distances are measured, they will be found to be equal. This principle is often used to stage illusions, such as ghosts, etc., on the stage.

Self-Testing Exercises (p. 401). 1. Image appears as far back in mirror as object is in front of mirror.

2. Light enters top of periscope where it strikes mirror placed at angle of 45°. Light is thus reflected down, where it strikes another mirror that again changes direction of light. When person looks at second mirror, he sees light that strikes first mirror.

3. In plane mirror person appears to be same size; in concave mirror, larger; and in convex mirror, smaller.

4. To collect and concentrate, or focus, all the rays of light and reflect them in a point on plane mirror which sends them through eyepiece.

Problems to Solve (p. 401). 1. Drawing should show three mirrors, one on either side and at an angle with a central mirror. (Other arrangements are possible.)

2. Thick glass reflects enough light to enable person to see himself.

3. Some are glass cut in such a way that they reflect practically all light that strikes them. They are similar to cut diamond. Others are made of prisms which reverse direction of light, and thus it passes back to the source. (Glass balls and polished metal also used.)

5. Plate-glass show window is set at angle so that bottom is farther back than top. Light striking smooth surface of glass is reflected down at an angle instead of straight back to eye. Show window is not visible. (Same principle is used to reduce glare from automobile windshields.)

6. Yes. Some light reflected from front surface of glass forms one image. Light reflected from silvered back forms brighter image. Part of light from bright image reflected back and forth inside glass, forming one or two other faint images.

PROBLEM 3: HOW DO WE USE LIGHT IN OUR HOMES? (P. 403)

From the standpoint of social value this problem is, of course, of prime importance. It is entirely practical in nature. No new science principles are introduced, but principles previously taught are applied to the problem of adequate lighting. Schoolrooms and homes will furnish abundant opportunity for first-hand observation. The local public-utility office may be able to send an expert in lighting to discuss and demonstrate the ideas treated in the problem. If the kind of light meter used to test room illumination (Figure 367) is not available, a photoelectric exposure meter used in photography will serve to demonstrate vividly variations in intensity of light. Some photography enthusiast in the class may own such a meter or a local photographer may be willing to loan one for a day or so. The major ideas of the problem are:

1. Our eyes are adapted to the primitive conditions under which they developed rather than to modern conditions.
2. Much of the trouble people have with their eyes results from using them under improper conditions.
3. The amount of light needed in the home varies according to the use made of the light.
4. Light may be measured in foot-candles by a light meter.
5. The intensity of light varies inversely according to the square of the distance from the source, and an allowance must be made for this in placing lamps.
6. Local lighting provides for specific kinds of uses of light.
7. General lighting for the room as a whole may be direct, semi-direct, or indirect lighting, each method having its advantages and disadvantages.
8. Correct lighting is so important that it is worth while to employ the services of an expert in arranging it or checking it.

EXPERIMENT 36. WHAT EFFECT DOES THE DISTANCE FROM A SOURCE OF LIGHT HAVE UPON ITS INTENSITY? (P. 407). Apparatus and materials needed are:

Candle or flashlight
Two pieces of cardboard, five inches square
Supports for cardboard
Shears
Ruler or yardstick

Figure 366, page 407, and the directions should make clear how the experiment is performed. Some pupil may be interested in carrying on a more exact experiment by means of a photometer, which may be borrowed from the physics laboratory.

Self-Testing Exercises (p. 409). 1. To outdoor conditions in which a great deal of illumination is provided and for long-distance vision.

2. Answers will vary. Samples are: *A* Hunting. *N* Reading. *N* Sewing. *A* Watching baseball or football game. *N* Writing. *N* Running machines in a shop. *N* Typewriting.

3. Pupil drawing should follow general scheme of Figure 366, page 407.

4. General lighting refers to lighting of room as a whole. Local lighting refers to lighting designed for special uses, such as reading, sewing, etc.

5. In direct lighting, light comes directly from lamp. In semi-direct lighting, part of light is direct but diffused by a translucent bowl. In indirect lighting, all light is reflected.

6. Answers may be arranged in tabular form.

METHOD	ADVANTAGES	DISADVANTAGES
Direct	Most economical method	May be glaring or unpleasant and injure eyes
Semi-direct	More economical than indirect method; more useful than direct lighting	Not so soft as indirect method
Indirect	Most nearly like diffused sunlight to which the eye is adapted	Least economical method

Problems to Solve (p. 409). 2. Figure 352, page 394, will help the pupil make his drawing. He should explain the drawing by reference to Experiment 34, pointing out that because the angle of reflection is equal to the angle of incidence, different rays of light emitted from the frosted globe cross each other and are therefore diffused.

PROBLEM 4: HOW DO WE USE LENSES? (P. 410)

The extremely wide use of lenses indicates that all educated persons should understand the general principles of the common optical devices in which lenses are employed. The concept of refraction is not one of the easiest for pupils to grasp, but fortunately there is a wealth of observational material close at hand, ranging from tumblers and pans of water to compound microscopes. So far as lens construction is concerned, the core idea is expressed in the paragraph at the bottom of page 410. Time permitting, make full use of any camera enthusiasts in the class. Frequently pupils are found who have a really scientific knowledge of camera lenses and operation. Someone may be able to bring an eight- or a sixteen-millimeter motion-picture camera and projector to class for demonstration.

The sub-problem beginning on page 416 has, of course, great personal value to the pupils. The text discussion is necessarily brief in a book of the scope of this one, but the material should be given full emphasis. If time permits and conditions warrant it, the teacher may care to supplement the text by a visit from an eye doctor or the school nurse and by reading and class discussion of some of the references listed on page 717. The major concepts of the problem are as follows:

1. A lens is a piece of curved glass that has the property of bending light rays.
2. The bending of the light rays is called refraction.
3. Convex lenses bend light rays inward so that they come to a focus.
4. The farther away a light is from a lens, the closer the focus to the lens.
5. The closer a light is to a lens, the farther back the focus from the lens.
6. Concave lenses bend light rays outward; therefore such rays cannot come to a focus.
7. The lens of the eye refracts all the rays of light which

strike the eye from any single point on an object and focuses them on one point of the retina.

8. By doing the same thing for all points on an object, the lens builds up an image, or picture, of the object on the retina.

9. The lens of the eye is focused by means of muscles which can cause a change of shape that changes the curvature of the lens.

10. The lens of the eye may be defective, causing near-sightedness, far-sightedness, or astigmatism.

11. Eyeglasses correct defects in the lens so that all rays of light are brought to a focus on the retina.

12. Certain precautions should be taken to prevent injury to or overfatigue of the eye muscles.

EXPERIMENT 37. HOW CAN A LENS BE USED TO PROJECT A PICTURE OF THE OUT-OF-DOORS? (P. 411). Apparatus and materials needed are: convex lens, cardboard, supports for lens and cardboard.

A reading glass such as is found in many homes may be used in this experiment. The scene will be inverted on the cardboard.

EXPERIMENT 38. HOW DO LENSES AFFECT RAYS OF LIGHT? (P. 411). Apparatus and materials needed are: two different double convex lenses (reading glasses), candle, matches, sheet of paper, ruler or yardstick.

The function of parts *a* and *b* of this experiment is to show that the distance behind the lens at which an object will be in focus depends upon the distance of the object from the lens. (Changes of object beyond fifty feet produce very slight changes in distance to focus.) The idea is the basis for understanding the camera. Part *c* of the experiment shows that the focal length of a lens depends upon its curvature. This idea is basic to the understanding of the eye.

SELF-TESTING EXERCISES (P. 415). 1. "Focus" refers to point at which rays of light passing through lens meet and form image.

2. Image is inverted (upside down).

3. Screen must be moved farther back.
4. Screen must be moved closer.
5. By moving lens in or out. Scale on camera shows distance and correct place to set lens.
6. More convex lens.
7. Rays are bent outward.

PROBLEMS TO SOLVE (P. 415). 1. Set up experiment such as Experiment 38. Keep candle at same distance from lens and measure distance from lens to card on which image of candle is focused. Lens which focuses image at shorter distance is more convex lens.

3. Convex lens focuses heat as well as light rays of sun on one point and thus concentrates them, while concave lens scatters rays.

4. Most view-finders are small telescopes arranged to work backwards and thus reduce apparent size of image instead of enlarging it. Some have mirrors to invert image. Others are like opera glasses, with concave lens at front.

5. Flat bottle will not act like lens. Spherical flask or watch crystals will.

SELF-TESTING EXERCISES (P. 420). 1. Muscles change pull of eyeball on lens to change its convexity.

2. Lens is too convex, or eyeball is too long. Corrected by use of slightly concave glasses.

3. Lens not convex enough, or lacking in elasticity, or eyeball too short. Corrected by use of slightly convex glasses.

4. Older people are often far-sighted because lenses lose some of their elasticity, so that they cannot become so convex as they formerly did.

5. (a) Be sure that you do not need glasses. (b) Look away occasionally when doing close work. (c) See that direct light does not shine in eyes while reading.

PROBLEMS TO SOLVE (P. 421). 1. May be done by discovering whether or not lens will bring rays of light from a candle to a focus. (See Experiment 38.) Convex lens corrects far-sightedness; concave, near-sightedness.

2. Bifocal glasses are ground with two different lenses in the same glass, one for ordinary vision and one for close work, such as

reading. Curvature or kind of glass used in the two lenses is different.

3. Muscles contract and cause pull of fibers on lens to lessen. This allows lens to become more convex.

SELF-TESTING EXERCISES (P. 424). 3. Convex lens focuses light on film that is drawn along at normal rate of 16 pictures per second. As each picture appears in front of lens, it stops for about one thirtieth of second. Shutter opens and allows light to pass through picture, which is enlarged and thrown on screen by another lens.

PROBLEMS TO SOLVE (P. 424). 1. Image of previous picture only remains on retina for fraction of second. If interval between pictures is too long, image will fade, and new picture will not merge with it.

2. Nearer to screen.

3. Water and glass of curved bottle acts as convex lens, magnifying olives. (See Problem to Solve 5, page 415.)

4. Screen is dark part of the time. The hand will be seen only at certain times (when the screen is lighted) and will seem to go jumping along. It may even be seen in several places at once.

5. Film run at high speed through camera, taking many more pictures per second. Film then run through projector at usual speed, producing slow-motion pictures, because action that may have taken only fraction of second to happen is stretched out to full second on screen.

PROBLEM 5: WHY ARE OBJECTS OF DIFFERENT COLORS? (P. 425)

Pupils are usually curious to know what causes the sensation of different colors. Prior discussion of reflection and absorption of light rays has paved the way for understanding color. If possible, the demonstration illustrated in Figures 387 and 388 should be carried out. An interesting study in color mixing can be made by examining colored pictures in magazines under a microscope. If there is a print shop nearby that does color printing, it might be possible to secure a set of old proofs showing each separate color and then the cumulative effect as one color is printed over another. These are known as "progressive color proofs." The main ideas of the problem are as follows:

1. White light or sunlight is a mixture of the seven colors that compose the spectrum.
2. Each kind of colored light has its own wave length.
3. Different kinds of light waves (colors) are bent differently when they pass into glass and can thus be separated by a prism.
4. If an object reflects all of the colors of sunlight equally, it is white; if it absorbs all colors, it is black.
5. The color of an object is determined by the kinds of light waves absorbed and reflected by it.
6. An object will have the color of the light waves that are reflected.
7. Colors appear different under artificial lights because artificial lights are not composed of exactly the same colors as sunlight.

EXPERIMENT 39. WHAT COLORS DOES SUNLIGHT CONTAIN? (P. 426). Apparatus and materials needed are: glass prism, white cardboard.

No difficulty will be encountered in this experiment. If a prism is not available, a broken piece of plate glass may be used by holding the edge in the beam of sunlight.

SELF-TESTING EXERCISES (P. 429). 1. When beam of sunlight passes through prism, band of seven colors is seen on cardboard held below prism (Experiment 39, page 426).

2. Each color has its own wave length, and each wave length is refracted to different degree from others.

3. Wave lengths of light corresponding to different colors reflected.

4. White reflects all colors equally. Since only red light strikes dress, only red will be reflected. Same is true when blue light strikes white dress.

5. Because artificial light does not emit same wave lengths or contains more or less of a given wave length of light. Artificial light usually contains less blue and more red than sunlight.

PROBLEMS TO SOLVE (P. 429). 1. Because of reflected light from objects around it. We really see the absence of light, which we interpret as black.

2. Diamonds and cut glass are cut in angles and really form many small prisms that break up light rays into colors.

3. Color film contains certain chemicals sensitive to certain wave lengths of light. Chemicals are changed when light of proper wave lengths strikes them. They are then replaced in an extremely technical process by pigments of appropriate color.

4. Drops of water in air refract light as does prism and also reflect it.

5. Glass is prism which bends light waves so that people can see cars on other side of hill. (Prisms are also used in field glasses for this purpose.)

LOOKING BACK AT UNIT 7 (P. 430). 1. See the problem analyses on pages 173, 175, 178, 180, and 184. Also refer to the unit graph on page 171.

3. *Luminous material:* produces and gives off light.

Transparent material: one through which light waves may pass without being absorbed.

Diffused light: scattered reflected light.

Focus: point of intersection of light rays from lens or mirror.

Indirect lighting: lighting by reflected light.

Image: picture formed by lens (or concave mirror).

Retina: coat of interior of eye that is sensitive to light.

Near-sightedness: occurs when lens of eye is too convex or eyeball is too long.

Reflected light: light that is not absorbed but bounces off object.

Angle of incidence: angle between ray of light and perpendicular to point where it strikes surface.

Regularly reflected light: whole beam of light reflected equally.

Direct lighting: light from source falls on object.

Convex mirror: curved outward in center.

Convex lens: thicker in middle than at sides.

Astigmatism: occurs when lens is not curved equally at all points. Result is blurring of lines running in certain directions.

Spectrum: seven colors of rainbow that are present in white light.

Opaque material: one through which light cannot pass.

Translucent materials: absorb some light, reflect some light, and allow some light to pass through.

Angle of reflection: angle between perpendicular and reflected ray. It is equal to angle of incidence.

Foot-candle: brightness of illumination produced by standard candle at distance of one foot.

Semi-direct lighting: part of lighting is direct and part is indirect.

Concave mirror: curved inward toward center.

Concave lens: sides of lens are thicker than middle.

Far-sightedness: occurs when lens is too flat or eyeball is too short. Nearby objects cannot be brought to focus.

ADDITIONAL EXERCISES (P. 430). 1. By constructing a drawing to scale or by dividing 120 inches (10 feet) by 8 inches. This shows that tree is 15 times as high as yardstick, or 45 feet.

2. Distance adjustment to bring picture to focus on film or plate. Diaphragm opening to regulate amount of light entering lens. Timing to measure amount of exposure to light. View-finder to show scene that will be reproduced on film or plate.

4. Aim rock below fish because fish appears higher in water than it really is. Light rays bent as they leave water, but eye sees rays as straight lines.

5. Rapid or fast lens will allow much light to pass through, making it possible to take picture with shorter exposure than with slow lens.

BULLETINS AND PAMPHLETS FOR UNIT 7

Bausch & Lomb Optical Company, Rochester, N. Y.
  Information about optical instruments, lenses, etc.
Eastman Kodak Company, Rochester, N. Y.
  Information about cameras, films, photography, etc.
Farmers' Bulletin
  No. 1838. *Electric Light for the Farmstead.* 10c
Public Health Reprint
  No. 1940. *Lighting for Low-cost Housing.* 5c
Standards Circular
  No. 389. *Making of Mirrors by Deposition of Metal on Glass.* 5c

VISUAL MATERIALS FOR UNIT 7

FILMSTRIPS

Society for Visual Education

- "Light"
- "Optical Illusions"

MOTION PICTURES

Encyclopaedia Britannica Films

- "Eyes" (elementary)
- "Illumination"
- "Light Waves and Their Uses"
- "Behavior of Light"
- "Lenses"
- "Optical Instruments"

UNIT 8

How Do We Use Electrical Current?

FUNCTION AND SCOPE OF UNIT 8. Unit 5 dealt with the elementary concepts of electricity, electric circuits, and generation of currents. This unit considers the ways in which electricity is measured and the main ways in which electric currents do useful things for us. The discussions of the various problems as well as the introduction to the unit are designed to bring about appreciation of the use of electricity both by realizing its manifold uses and by understanding how it has been put to work in the different devices we use every day.

Useful background material not treated fully in *Book 3* includes acquaintance with elements, compounds and chemical change (*Book 1*, Unit 5), magnets and magnetism (*Book 1*, Unit 7), the forms of energy and their changes (*Book 2*, Unit 5). Essential background in this book is Unit 5 and Problems 1 and 2 of Unit 6 (the nature of sound).

INTRODUCTORY EXERCISES (P. 432). *1. Flashlight contains two or three small dry cells which by chemical action generate electrical current. When button is pressed, electric current is led through a very fine wire inside bulb of flashlight. Resistance of this wire changes electrical energy into heat and makes wire white-hot to give out light.

2. Iron contains a rather long piece of wire that has a high electrical resistance and gets quite hot when current of the proper strength is sent through it. (See Figure 397, page 439.)

3. (*a*) The rate at which work is done by an electrical current of one ampere flowing under one volt of pressure. The number of watts (power) of a current is found by multiplying number of volts by number of amperes. (*b*) One thousand watts.

4. (*a*) 4852. (*b*) Kilowatt-hours.

5. Pressing button closes switch so current can flow through complete circuit including the bell. Flowing through electromagnet in bell, current causes magnet to attract bar of iron, make clapper strike bell and open a switch that shuts off current. Spring pulls iron and clapper back closing circuit. Action is repeated.

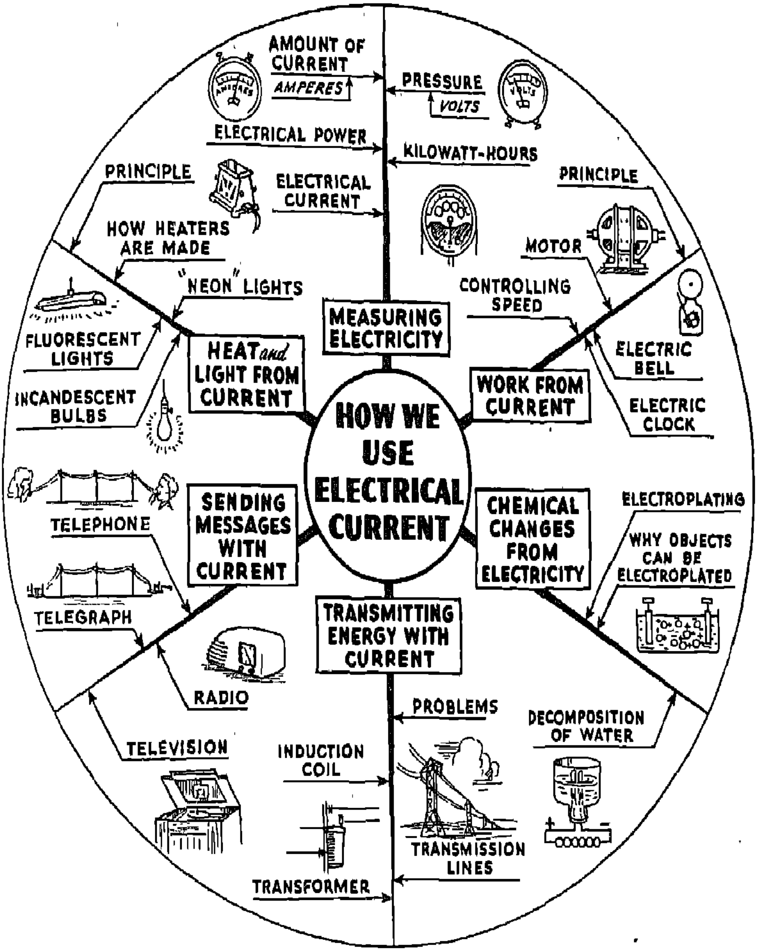


FIG. 13. GRAPH OF THE SUBJECT MATTER OF UNIT 8

6. Lists vary. Common examples are for lifting iron and steel, in telephone receivers, electric generators, motors, telegraph sounders, relays, radio loud-speakers, electric train switches, couplers and controllers, induction coils, etc.

7. Electromagnets produce a strong magnetic field about armature. Wires on one side of armature carrying current in one direction tend to move upward. Wires on the other side carry current in opposite direction and pull downward. Thus armature turns. Commutator keeps current flowing right way in wires on armature.

Another common way of explaining: Field magnets attract poles of armature magnet until they turn and reach poles of field magnets. At that point commutator reverses poles of armature magnet, causing them to be repelled by magnets that had just been attracting them. Thus they move on around to next magnet where they are again reversed. This rotation is kept up.

8. Dish of solution of a silver compound, some electric cells and a direct current generator, piece of silver, connecting wires. For a diagram of essentials see Figures 419 and 420, pages 466 and 467.

9. Two or more coils on a core made of layers of soft iron. Changes the 115- or 120-volt house current to a lower voltage that is safe to use in operating the electric train.

10. The transmitter into which one speaks is a microphone. The receiver contains an electromagnet. The former uses sound to make an electric current vary. The latter uses a varying electric current to make sound.

11. (a) The set must be made so that its electrical circuit will allow electrons to oscillate in time with (in tune with) the sending station. (*b*) The aerial gives the radio waves coming through space more opportunity to cause oscillations of electrons in the wires of the receiving set. (c) The amount of energy received from the radio waves is not enough to make strong sound waves. Energy to do this is added from the electric current. Electric current is also needed to heat the parts of the radio tubes and make them operate.

LOOKING AHEAD TO UNIT 8 (P. 433). The discussion in the textbook is intended to bring out the following: (1) Electric current is a servant more wonderful than any genie conceived by story-tellers of olden times; (2) The really different ways of using electric currents are few, and you can understand them reasonably well if you will try. The teacher may well reach the same end by having the class name all the uses of electric current they know and then group together all those that use heating effects, magnetic effects, chemical effects, etc. He may wish to tell stories of the efforts to make successful incandescent lights, telegraph lines, telephones, radios, etc., to develop appreciation of the efforts that have given us modern electrical wonders. Background material for such introductory remarks may be found in some of the books listed in the text for Unit 8.

PROBLEM 1: HOW DO WE GET HEAT AND LIGHT FROM ELECTRICAL CURRENT? (P. 435)

Problem 1 deals with what are probably the most common uses of electrical currents. It includes the useful application of a principle introduced in Unit 5, Problem 2, namely, that because of the resistance of conductors to the passage of a current, electrical currents always produce heat. The main ideas developed in answering the problem are:

1. The heating effect of an electrical current is greater where the resistance to the current is greatest.
2. A large current flowing through a conductor produces more heat than a small one.
3. For each electrical current situation (voltage and resistance of conductor) there is a certain length of wire that will become red-hot or white-hot.
4. Ordinary heating devices use high-resistance conductors to produce their heating effects.
5. Incandescent light bulbs use the same principle as heaters but have wires protected from oxidation that become much hotter; even though they produce much light, incandescent bulbs change more energy into heat than into light.
6. Modern "neon" tube lights and fluorescent lights glow because of an electrical current passing through the gases inside the tubes; each different gas gives out its own distinct color of light.

EXPERIMENT 40. UNDER WHAT CONDITIONS WILL A DRY CELL HEAT A WIRE RED-HOT? (P. 436). The apparatus and materials needed are:

Thirty inches of No. 30 bare copper wire
Thirty inches of insulated copper wire, No. 18 or larger
Two large nails
Board at least 26 inches long and ½ inch thick
One dry cell

As the sliding contacts are moved close together, the small wire gets hotter and hotter and may melt and fall apart. The larger insulated wires may become warm.

SELF-TESTING EXERCISES (P. 440). 1. A kind of electrical friction that is met in all conductors and changes electrical energy into heat.

2. Heating wire becomes much hotter than copper wires that carry current in other places because this wire has higher resistance to current than copper wire has.

3. High electrical resistance, high melting point, high resistance to oxidation.

4. The resistance is so high that it allows only a small amount of current to pass through. This would not give out enough heat to toast bread.

PROBLEMS TO SOLVE (P. 440). 1. (*a*) Wire might be made shorter. It is clear that there is not enough current flowing through wire. Shorter wire would have less resistance and allow more current to flow through. (*b*) Increase voltage in some way.

2. Copper and aluminum wires are not too expensive to use and have lowest electrical resistance of any common metals.

3. Results of this project will vary with devices studied. A class report with an exhibit should be prepared.

4. Any wires secured may be tried out under proper supervision. Proper precautions must be taken against shock and fire hazards.

SELF-TESTING EXERCISES (P. 446). 1. Diagrams may show a wide variation and yet be acceptable. The essentials are: two exterior connections, airtight glass bulb, continuous circuit from the exterior connections through filament, space in the bulb for vacuum or special gas. Labels are shown in table at top of page 193.

PART	USE
Glass bulb	Separates gas or vacuum inside from air and lets light through; supports filament
Filament	Conducts current but has high resistance to change electrical energy into heat and light
Connections	Carry current between exterior wires and filament
Vacuum or gas-filled space in bulb	Prevents burning (oxidation) of filament

2. (*a*) Carbon threads. (*b*) Tungsten wires now used because of high melting temperature, proper strength, and resistance.

3. Main disadvantage of modern electric light bulbs is that they change about 95 per cent of electrical energy into heat.

4. Tube contains small amount of some gas. By means of transformer electricity at high voltage is sent through gas and causes it to glow with light.

5. (*a*) Two electrodes connected to a source of current are touched together and then separated a short distance. Current leaps gap and makes a very brilliant light and heats gas in gap to very high temperature. (*b*) Make light, produce ultra-violet rays, produce extremely high temperatures in furnaces and for welding.

6. No. A metal rod and metal parts to be welded form electrodes when electric arc-welding is being done.

PROBLEMS TO SOLVE (P. 446). 1. High; because so high a temperature is produced in the arc.

2. One connecting wire is soldered to brass screw on base, other to metal disc at end of base. Wires are usually separated by piece of cotton or some similar material, although air may be only insulating material. Tube through which air was exhausted will be found inside base of bulb with projecting end sealed. Filaments of all modern bulbs are formed of tiny closely wound spirals.

PROBLEM 2: HOW IS ELECTRICITY MEASURED? (P. 446)

Understanding of the quantitative phases of electricity is so commonly useful that this problem fills a real need in the lives of both boys and girls. Moreover, the discussion of the problem is carried only as far as is necessary for intelligent use of common terms. Abundant opportunity for study of actual electrical bills and labels on electrical devices should be provided in all communities where electricity is used. The main ideas developed in the problem are:

1. Electrical pressure is measured in terms of volts, a dry cell producing about 1.5 volts.
2. The size of an electrical current is measured in terms of amperes; a 60-watt light bulb at 110 volts of pressure allows little more than one-half an ampere of current to flow, and an electric iron uses about five amperes.
3. The power (or rate of working) of an electric current is measured in terms of watts; the number of watts is found by multiplying the number of amperes by the electrical pressure in volts.
4. The amount of electrical energy we buy is measured by the number of watts used and the time they are used; watts multiplied by hours gives watt-hours (or kilowatt-hours when divided by 1000) of energy.

LEGEND FOR FIGURE 403 (P. 447). The diagram on the left shows 1.5 volts of electrical pressure; the one on the right, about 110 volts.

LEGEND FOR FIGURE 404 (P. 448). The circuit on the left is carrying .9 ampere; that on the right, 5.2 amperes.

SELF-TESTING EXERCISES (P. 449). 1. See table below.

WATER		ELECTRICITY		
WHAT IS MEASURED	UNITS	WHAT IS MEASURED	UNITS	INSTRUMENTS
Pressure	Pounds per sq. in.	Pressure	Volts	Voltmeter
Rate of flow	Gallons or cu. ft. per minute	Rate of flow	Amperes	Ammeter

2. (*a*) 110-120 volts. (*b*) Answers may vary widely. The reading material has mentioned: 60-watt light, .54 ampere; 100-watt light, .9 ampere; electric iron, .52 ampere.

PROBLEMS TO SOLVE (P. 450). 1. Scientifically defined, a volt is amount of pressure that will force one ampere of current through a column of mercury of a certain cross-sectional area and of certain length.

2. An ampere is amount of electrical current which will deposit a certain amount of silver from solution upon a plate under certain standard conditions.

3. From Figure 404, one 100-watt light requires .9 ampere. Seven would require 6.3 amperes.

4. 17 bulbs (15 ÷ .9 = 16.7). Fuse should "blow" when seventeenth bulb is turned on.

SELF-TESTING EXERCISES (P. 451). 1. A 1000-watt motor is capable of doing work twice as fast as a 500-watt motor.

2. Power in watts equals number of volts of pressure multiplied by number of amperes of current flowing through the device.

3. 495 watts (4.5 amperes × 110 volts).

PROBLEMS TO SOLVE (P. 451). 1. Divide number of watts of power required by voltage for which it was designed.

2. 7.27 amperes (800 watts ÷ 110 volts).

3. (a) 17.97 amperes (575 watts ÷ 32 volts). (*b*) 5.23 amperes (575 watts ÷ 110 volts).

4. 9.6 bulbs (575 watts ÷ 60 watts).

LEGEND FOR FIGURE 408 (P. 454). Dial reads 4852 kilowatt-hours. 314 kilowatt-hours of energy used during month.

SELF-TESTING EXERCISES (P. 454). 1. Amount of energy used when an electrical device has used power at rate of one watt for one hour. Kilowatt-hour is 1000 watt-hours—1000 watts of power used for one hour, 500 for two hours, 100 for ten hours, etc.

2. 1350 watt-hours, or 1.35 kilowatt-hours of energy (450 watts × 3 hours).

3. 400 watt-hours of energy (800 watts × ½ hour).

PROBLEMS TO SOLVE (P. 455). 1. (a) 1440 watt-hours or 1.44 kilowatt-hours (60 × 24). (*b*) 7.2 cents (1.44 × 5 cents).

2. 6.75 cents (1.35 kilowatt-hours × 5 cents).

3. Answers vary with the community and often with the amount of current used. Usually the first part of a month's usage is charged at one rate, a second part at a lower rate, and the remainder at a still lower rate. Ordinarily there is also a minimum service charge.

PROBLEM 3: HOW DO ELECTRICAL CURRENTS DO WORK? (P. 455)

The importance of electric motors is indicated in the first paragraph of the discussion of this problem. However, many simple devices use electromagnets to do small amounts of work at a distance from the person controlling them. The electric bell has been chosen as a common example of this class of devices. Discussion of the bell reviews the action of electromagnets and lays the foundation for understanding other such devices when they are met.

The action of motors is explained not by the attraction and repulsion of magnetic poles as is usually done but by the tendency of a current-carrying wire to move in a magnetic field. The authors are convinced that the latter form of the same general principle is much easier to apply to commercial motors. The main ideas included in the discussion of the problem are:

1. An electric bell employs a device called an electromagnet to do work; the magnet is a piece of iron of suitable shape wrapped with many turns of wire; when a current passes through the wire the iron is magnetized and pulls on a nearby piece of iron which does the work of striking the bell.

2. Any wire carrying an electrical current in a magnetic field tends to move; if either current or field is reversed, the wire will tend to move in the opposite direction.

3. In an electric motor there are

a) electromagnets (or permanent magnets) to create a strong magnetic field;

b) a rotating armature on which are wires that carry current through the field and so cause the turning of the armature;

c) devices for carrying the current into the wires on the armature; to cause continuous rotation, these devices must keep the current always flowing in the same direction on a given side of the armature.

4. Modern electrical motors are carefully designed to get as strong and smooth a turning force as possible and so turn a very high percentage of the energy they use into kinetic energy.

5. Synchronous motors used in electric clocks keep in perfect step with the generators because of pulses in the alternating current they use.

6. Electric motors do not harness energy; they merely aid in transmitting and applying energy some other device has brought under control.

SELF-TESTING EXERCISES (P. 458). 1. Insulated wire is wrapped many times about piece of soft iron called core. When an electric current is sent through wire iron becomes a magnet.

2. Current flowing through coils of electromagnet causes core to attract a piece of iron to which clapper is attached.

3. Iron armature that is attracted by magnet has a small switch, or contact point, attached to it. When it is pulled over against magnet, current is shut off and a spring pulls it back again. This action is repeated over and over.

EXPERIMENT 41. HOW DOES AN ELECTRIC WIRE MOVE IN A MAGNETIC FIELD? (P. 458). The apparatus and materials required for this experiment are:

Strong U-magnet
Dry cell
Three feet of fine (No. 30 or smaller) insulated copper wire
Push-button or switch
Supporting device for magnet and wire (A ringstand with two rings is quite convenient.)

This experiment is easily done and extremely significant. The movement of the wire in the magnetic field can be increased by using two or more magnets laid one on top of the other or by using two dry cells connected in series. Make sure that N-poles of the magnets are all laid together. Two or more good bar magnets may be used in the place of a U-magnet. Lay the S-pole of one magnet opposite the N-pole of the other and hang the vertical wire between.

Experiment 42. How Is an Electric Motor Constructed? (p. 460). Apparatus and materials needed are:

- One or two large U-magnets
- Cylinder of cork, balsa wood, or soft pine one inch in diameter and two inches long
- Steel knitting needle or two long slender nails
- 12 feet of No. 20 or No. 22 insulated copper wire
- Four feet of No. 18 cotton-covered wire
- Two dry cells
- Hammer
- Pliers
- Knife
- Thread

The motor to be made for this experiment is one of the simplest to construct. When made with reasonable care, it is almost sure to run quite rapidly.

Figures 413-415, pages 460-461, show clearly the plan of constructing and operating the motor. Boys skilled in construction may wish to add a second armature coil and set of commutator pins (nails or copper wires).

Self-Testing Exercises (p. 465). 1. (*a*) Wire moves or tends to move sidewise. (*b*) When current is reversed, it moves or tends to move in opposite direction.

2. When current is sent through wires on armature, wires will not tend to move unless they are in a magnetic field. Field magnets make strong magnetic field around and through armature.

3. On one side of armature are wires in which current flows in one direction. On other side are wires in which current flows in opposite direction. Wires on one side pull up, and on other side they pull down. Because of these pulls in opposite directions, armature turns.

4. Brushes and commutator are used to make connection between moving wires on armature and stationary wires on outside. Commutator also changes connections so that every wire that comes to one side of motor has current flowing in same direction. This keeps all wires on that side pulling in same direction.

5. A motor that keeps in time with generator or with pulses of an alternating current. Such motors are used in modern electric clocks and phonographs.

6. Because they transmit energy from place where it is harnessed to places where it is to be used.

PROBLEMS TO SOLVE (P. 465). 1. Armature with only one coil like that of model motor used for Experiment 42 has times during each rotation when it is pulling strongly and other times when it is not pulling at all. By addition of more coils in different positions around armature some coil or coils will always be pulling. This will make motor run more smoothly and be "stronger."

2. Each wire tends to pull armature around with a certain amount of force. Thus more wires there are, stronger the motor is.

3. Electromagnets can be made much stronger than permanent magnets. This is the chief advantage.

5. Arrangements of belts and pulleys and of gears are used to reduce speed of motors.

6. Both parallel and series connections for field magnets and armature are possible. Each plan, as well as a combination of the two, is used to meet different operating conditions for which motors are needed. Diagrams in Figure 7 on page 147 of the *Guidebook* shows how the connections can be made. Pupils' diagrams will, in all probability, vary widely, but they should show the essential connections clearly.

7. Induction motor has complicated series of alternating current connections to field magnets. Field magnets produce magnetic field that turns. Turning field generates current in armature, making armature a magnet. Magnetized armature follows turning field.

PROBLEM 4: HOW IS ELECTRICAL CURRENT USED TO CAUSE CHEMICAL CHANGES? (P. 466)

One of the important ways in which electrical currents are used is to cause chemical changes by action on ions in solutions or molten substances. This use is not often met directly by boys and girls except in storage batteries. (The products are of course familiar in the form of electroplated articles, aluminum, and books printed from electrotypes.) Yet a large percentage of pupils are invariably interested. Electroplating and electrolysis of water seem like magic. This will often be the first time pupils have seen the evidence that water is actually a compound of hydrogen and oxygen, H_2O. The main ideas brought out are:

1. From a dissolved compound of metal a direct current deposits the metal in a thin layer on any conductor suspended in the solution and connected to the negative wire of the current source.
2. Electric currents are widely used to cause chemical changes such as the decomposition of water and the manufacture of chlorine gas and aluminum metal.
3. Electric currents can cause chemical changes because certain compounds are composed of charged atoms (or groups of atoms). When electrical charges are added to or removed from atoms, chemical changes occur.

EXPERIMENT 43. HOW IS COPPER PLATING DONE? (P. 466). The apparatus and materials needed are:

Glass tumbler or beaker
Silver coin
Soap and brush
Sulphuric acid, few drops
Insulated copper wire, 2 1-foot pieces
Strip of copper or small coil of bare copper wire
Water, 1 pint
Copper sulphate, 2 ounces
Dry cell
Paper clip

This experiment is invariably successful although the quality of the plating varies. Commercially, the quality of the metal coating is varied by varying amount of current used, concentration of the solution, other ingredients, and length of time.

EXPERIMENT 44. HOW IS WATER DECOMPOSED? (P. 468). The apparatus and materials needed are:

Some form of electrolysis apparatus (See Figures 422 and 423 and directions on pages 468-469 in the text.)
Sulphuric acid, 10-12 cc.
Dry cells, 2-6
Insulated copper wire, 3 feet
Water, 1 to 2 pints
Matches
Wooden splinters

In a commercial electrolysis apparatus no difficulties should be encountered if good electrical connections are made. The testing of the gases often requires some ingenuity. In the home-made apparatus exposure of copper to the solution may cause the formation of copper sulphate, and the proportions of the gases may not be exactly two to one.

SELF-TESTING EXERCISES (P. 471). 1. Object to be plated connected to negative electrode of direct current source and suspended in a solution of an appropriate compound of the metal to be plated. Positive electrode of metal to be plated immersed in solution.

2. (*a*) Type set; (*b*) type pressed into soft wax and removed; (*c*) wax coated with graphite to make it conduct current; (*d*) wax electroplated with copper (or other metal); (*e*) copper sheet removed from wax and backed with lead (or type metal).

3. Negative (or zinc), because metallic ions in solution have positive charges. Thus they will be attracted to the article and discharged.

PROBLEMS TO SOLVE (P. 471). 1. Because when the current reverses it undoes all it did going in the first direction. Any metal deposited at one moment is removed when the current goes the other way during the next moment.

2. Negative. Hydrogen ions are positive ions.

PROBLEM 5: HOW IS ELECTRICAL ENERGY TRANSMITTED TO OUR HOMES? (P. 472)

This unit has been planned to make common electrical devices intelligible in terms of the simpler principles by means of which they operate. Everyone who travels about at all sees many transmission lines and the transformers connected with them. Problem 5 is included to bring out the part these devices play in the distribution of energy by means of electric currents after the current has been harnessed by power machines. The main ideas are:

1. Much less electrical energy is lost as heat when transmitted by means of a small current at high voltage than when

the same amount of energy is sent by means of a large current at low voltage.

2. Electrical engineers therefore use very high voltages of electricity when they need to send current long distances; the voltage is increased and decreased by means of transformers.

3. In transformers an alternating current flowing through one coil generates a similar alternating current in another coil.

4. The voltage in the second (secondary) coil is raised or lowered according to whether the second coil has more or fewer turns of wires than the first (primary) coil; the size of the current is lowered when the voltage is raised, or vice versa, so that the energy transmitted remains the same except for a slight loss within the transformer.

EXPERIMENT 45. HOW IS A TRANSFORMER MADE? (P. 475). The apparatus and materials required are:

Soft iron rod bent into 3- or 4-inch circle (or rectangle), or two short U-shaped pieces that fit together
Ten feet of insulated copper wire
Push button or switch
Dry cell
Galvanometer

The winding of the coils on the transformer is much easier if the core is made of two pieces that can be fitted together and fastened with tape after the coils have been completed. Another variation is to place two coils side by side on a straight iron rod. When the circuit is completed so that the current can begin flowing, the galvanometer needle swings in one direction. When it is broken, so that the current must stop, the needle swings in the opposite direction.

SELF-TESTING EXERCISES (P. 478). 1. With low pressure there is too much loss of energy in wires. Lost energy is changed into heat.

2. Alternating current flowing through coil in transformer generates, in coil of many times more turns of wire, smaller current of much higher voltage.

3. High-voltage alternating current flowing through coil in transformer generates, in a coil of fewer turns of wire, larger current with lower voltage.

4. Such a "transformer" is commonly called an induction coil. Instead of the alternating current in the first or primary coil, the direct current is stopped and started very suddenly much as was done in Experiment 45.

PROBLEMS TO SOLVE (P. 479). 1. Answer should give details of construction, tell how current is interrupted, and tell how breaking primary current causes lines of magnetic force to collapse and move across secondary current, thus generating a high voltage there.

2. High voltage is needed for neon lamps. Induction coil or transformer used to produce necessary high voltage from low voltage current.

3. Voltage would be at least five times higher than that for which the train motor is designed, too much current would flow through wires in motor. They would overheat and burn off insulation ruining motor unless a fuse in house circuit blew out first. It is possible that train, or at least motor, would run very fast for a few moments.

4. Various arrangements are used in different engines.

PROBLEM 6: HOW IS AN ELECTRICAL CURRENT USED FOR SENDING MESSAGES? (P. 479)

This problem presents material of gradually increasing difficulty, beginning with the telegraph and ending with television. Throughout the study of the problem the teacher should have two thoughts in mind in connection with the principal ideas which are to be mastered by the pupils: first, the study should be made concrete rather than abstract in every way possible; second, the pupils should be prepared for the fact that the commercial systems of communication are much more complicated than the ones presented in the text and that they will not be able to understand all the details of the commercial systems without much study.

The first thought should result in having as many of the instruments as possible in the classroom or laboratory in working order, and in encouraging the pupils to observe all the facts they can about the telegraph and telephone systems they know. The result of the second should not be that the pupils are made to feel that what they are learning is not true and not always applicable, but that the details of application are so variable and so complicated that, unless one spends much more time in their study than is available in a science course, he cannot hope to master them. The concepts and principles to be emphasized in this problem follow:

1. Modern telegraph systems are quite complicated, but the principles involved may be understood by the study of simple instruments.
2. The essentials of a telegraph circuit are a source of current, conductors for the current, a key of some kind to make and break the circuit, and an electromagnet and armature which make audible clicks as the armature is attracted and released by the magnet.
3. In the transmitter of a telephone circuit, the sound waves alternately compress and release carbon granules inside a small box; the current flowing through these granules is thus made to increase and decrease in time with the sound waves.
4. As the transmitter causes the current in the circuit to vary, an electromagnet in the receiver is strengthened and weakened. As its attraction changes, a metal diaphragm vibrates and sends out sound waves similar to those striking the transmitter.
5. In a radio transmitting set, electromagnetic waves of high frequency are set up in the aerial by a generator.
6. In a radio receiving set, the aerial is tuned to the frequency of the sending set to which one wishes to listen.
7. In the broadcasting station a microphone sets up a pulsating current that changes the radio waves that are being sent out according to the kinds of sound waves that strike the microphone.
8. Radio tubes are used to change the high-frequency alternating current of the aerial to a pulsating direct current and to amplify the weak currents so that they may operate loud speakers.
9. In television, light waves are used to change the strength of the current sent out by the aerial.

10. The scene televised is lighted by a strong light and reflects different amounts of light according to its lightness and darkness.

11. The reflected light from the scene sets up a pulsating current in a camera-like device and controls the strength of the high-frequency waves sent out by the sending station.

12. These high-frequency waves are changed back to pulsating waves at the receiving end, and a special tube controls the production of the light forming the scene that we see.

EXPERIMENT 46. HOW IS A SIMPLE TELEGRAPH INSTRUMENT SET UP AND OPERATED? (P. 480). Apparatus and materials needed are:

Dry cell
Two feet of insulated copper wire
Sending key
Sounder (or apparatus in Figure 435, page 481)

The armature of the sounder shown in Figure 435 is made of a strip of a stovepipe iron. The key is a strip of brass, copper, or iron to which a cork is attached.

SELF-TESTING EXERCISES (P. 483). 1. When sending key is pressed down, current of electricity flows through electromagnet of sounder, and force of electromagnet pulls armature down with a click. When key is released, armature is pulled up by spring and makes second click.

2. To open and close circuit through electromagnet of sounder.

3. Teletypewriter is a machine that receives electric impulses and automatically reproduces letters to which they correspond.

SELF-TESTING EXERCISES (P. 487). 1. Pulsating current (or alternating current).

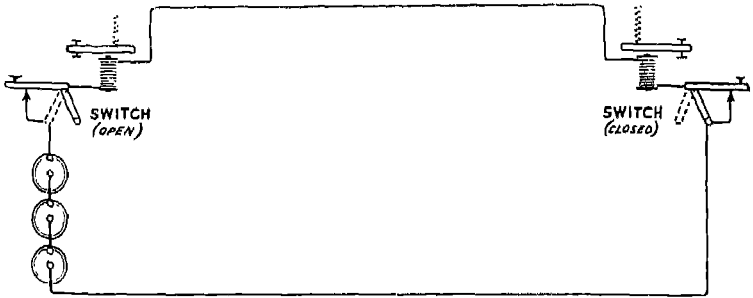
2. Sound waves by alternately compressing and releasing carbon granules vary strength of current which flows through transmitter.

3. Current in receiver pulsates according to nature of sound waves which vary current strength. As current pulsates, diaphragm in receiver moves out and in and sets up sound waves which pass to ear of person listening.

4. Simplest telephone circuit will have transmitter and receiver connected in series with dry cell.

PROBLEMS TO SOLVE (P. 487). 1. Nails should not be placed so far apart that earth offers so much resistance as to make it impossible for apparatus to operate. Pouring a little water on ground where nails enter will help increase conductivity of earth. Perhaps it will be necessary to use more than two cells. If so, cells should be connected in series.

2. Telegraph circuit will have sounder and key at each end connected in series with sounder and key at other end and with battery. Switch at either end short-circuits key so that messages sent from other end can be received. (Only one wire is needed if ground connection is used with each set.)



(THIS WIRE MAY BE OMITTED AND GROUND CONNECTION USED)

FIG. 14

4. (*b*) For long-distance communication simple set described above will not work. Resistance of long wire to flow of electric current is so great that a few cells cannot send enough current to operate sounder. To overcome this difficulty, a *relay* is used in each station. Relay has electromagnet with many turns of wire, and a very light-weight armature, which is easily moved. Slightest current will, therefore, cause enough magnetism to pull armature down. Local circuit includes battery, sounder, and relay armature. When relay armature is pulled down, local circuit, operated by cell, is closed. Relay therefore serves to make and break local circuit which operates sounder.

7. Local telephone company is usually quite willing to show operation of telephone exchange. Company uses the occasion to educate public on use of telephone.

SELF-TESTING EXERCISES (P. 493). 1. By setting up high-frequency currents in aerials by means of transmitter (oscillator).

2. "Tuning" a receiving set means changing frequency of receiving aerial so that frequency is same as that of sending aerial. It must be in tune with sending aerial so that it will respond sympathetically.

3. Change strength of radio waves that are being sent out from aerial.

4. To operate radio tubes and produce enough power to operate electromagnets of loud speaker.

5. To change high-frequency alternating current to pulsating direct current, to amplify current.

6. Television is a process in which light from a scene controls strength of electrical current sent out by radio waves which operate receiver reproducing original scene.

PROBLEMS TO SOLVE (P. 493). 1. Table below gives differences:

BASIS OF DIFFERENCE	SOUND WAVES	RADIO WAVES
Means of production	Vibrating material	Oscillating electricity
Medium of transmission	Air or other form of matter	Air or empty space
Rate of travel	1100 to 16,000 feet per second	186,000 miles per second
Distance of travel	Quite limited	Thousands of miles
Frequency	18 to 15,000 vibrations per second	10,000 to 400,000,000 vibrations per second
Ability of human body to produce and detect	Present	Absent

2. Two main uses of radio tubes are as amplifiers and rectifiers. They are also used as oscillators. Some are actually two or more tubes in one. In all radio tubes electrons are emitted by a heated filament and attracted to a positively charged plate. In all tubes but rectifiers a grid controls the flow of electrons to the plate.

3. Two kinds of condensers used in radio sets: variable and fixed. Variable condensers are used for tuning. Fixed condensers are

used to transmit alternating currents (but not direct currents). In rectifiers built into radio sets fixed condensers help smooth out rectified current.

4. Two general changes are made: variable condensers change the capacity of the circuit, and coils change inductance. Both changes help tune circuit.

LOOKING BACK AT UNIT 8 (P. 493). 1. (a) Production of heat by electric irons, toasters, soldering irons, etc. Electrical energy is changed to heat energy.
b) Production of light by incandescent bulb filaments, neon signs, fluorescent tubes, arcs, etc. Electrical energy is changed to light energy.
c) Production of magnetic force by electromagnets, motors, etc. Electrical energy is changed to kinetic energy (motion).
d) Causing of chemical changes in electroplating, electrolysis, manufacture of aluminum, charging of storage batteries, etc. Electrical energy is changed to chemical energy.
e) Sending out of radio waves by radio transmitter and television transmitters. Electrical energy is changed into energy of radio waves (a form of radiant energy).

2. *Resistance:* electrical friction that changes some of energy of an electrical current into heat.

Incandescent bulb: contains a fine wire, the *filament*, which is heated so hot by an electric current that it gives out light.

Filament: tiny wires in electric light bulb heated white-hot by current to give light.

Frequency of radio waves: the number of waves that are sent out in a second.

Radio waves: a kind of invisible radiant energy sent out by rapid oscillations of electricity in a conductor.

Arc (electrical): the exceedingly bright and hot gas that conducts electrical current across a gap between two electrodes that have been touched together and separated.

Volt: a unit of electrical pressure The ordinary dry cell produces a pressure of about 1.5 volts.

Watt-hour meter: used to measure the amount of electrical energy used by any device or consumer.

Magnetic field: the area in which the force of a magnet acts.

Ion: an electrically charged particle in a solution (or in the air).

Commutator: In an electrical generator it changes alternating current to direct current for use in outside wires. In a motor it makes the current flow always in the same direction through the wires on a given side of the armature.

Brushes: In electrical generators *brushes* rub on a commutator or on slip rings to connect these turning parts with the stationary wires.

Electrolysis: production of chemical change by electrical current.

Transformer: device to raise or lower the voltage of an alternating or interrupted direct current by means of two coils on an iron core.

Secondary coil: coil in which current is generated in a transformer.

ADDITIONAL EXERCISES (P. 494). 1. (*a*) Battery too weak because of too few cells, wrong connections, or worn-out condition. (*b*) Wires too long or too small. (*c*) Poor connections somewhere. (*d*) Magnets in bell have too few turns. (*e*) Clapper of bell and armature that works it bent out of correct position.

3. Heating coils in electrical range use much more current and thus require larger wire to carry current to them. Also, electrical companies often give cheaper rate for electricity used in cooking, and this calls for separate meter.

5. Because induction coil that is connected to spark plugs is generating pulses of electrical current at very high voltage.

6. The report may well be a diagram of the electrical system together with a description of any parts not studied by the class.

8. Horns are operated in at least two ways: (*a*) by vibrations produced by an electromagnet somewhat as an electric bell operates and (*b*) by vibrations produced by a small motor.

9. Current in automobile starting and lighting systems must be direct current in order to charge storage battery. Since current needs to be transmitted for only short distance, there would be little gain in use of alternating current.

BULLETINS AND PAMPHLETS FOR UNIT 8

Bell Telephone Laboratories, New York
Information about sound and communication

Rural Electrification Administration
Electric Power on the Farm. 25c
Electrifying Your Farm and Home. 10c
Standards Circular No. 408. *Information for Amateur Designer of Transformers for 25- to 60-Cycle Circuits.* 25c
U. S. Office of Education, Vocational Division
Bulletin 209. *Building Electrical Equipment for the Farm.* 20c

VISUAL MATERIALS FOR UNIT 8

FILMSTRIPS

Society for Visual Education
"Telegraph"
"Telephone—Central Station"
"Telephone—Outside"
"Radio—Historical"
"Radio—Marine, Aviation, etc."
"Broadcasting—Studio"
"Broadcasting—Outside"
"Television"

MOTION PICTURES

Encyclopaedia Britannica Films
"Chemical Effects of Electricity"
"Magnetic Effects of Electricity"
"Electric Power in the Southern Appalachians"
"Induced Power"

UNIT 9

How Do We Harness the Energy of Nature to Do Our Work?

FUNCTION AND SCOPE OF UNIT 9. Without the constant and immense supply of energy obtained from running water and from fuels our modern world would collapse. A sound understanding of the basic facts and principles which are applied in bringing this energy into useful form and controlling it properly is an important part of general education. The purpose of this unit is to develop that understanding.

At first thought one might feel that electric motors should be included among the "power" devices studied in this unit. These motors are excluded, however, when we see that windmills, water-wheels, steam engines and turbines, and internal-combustion engines together with the muscles of animals (all called *prime movers* by engineers), are the means of bringing under control the supplies of energy found in nature. Electric generators and motors then serve as useful devices in the transmission of the energy that has been harnessed.

During the study of the unit effective use can be made of pupil reports on the historical development of water power, steam engines, and internal-combustion engines. Especially in connection with the steam engine, effective correlation with social studies can be developed. The teacher should, if possible, develop in the class a consciousness of the social effects of the whole group of devices studied in the unit.

The following background material from *Books 1* and *2* is useful in the study of Unit 9:

Book 1

Unit 6. Fuels and the methods of controlling fire.

Book 2

Units 4 and 7. Why winds blow and how rainfall is produced on the highlands.

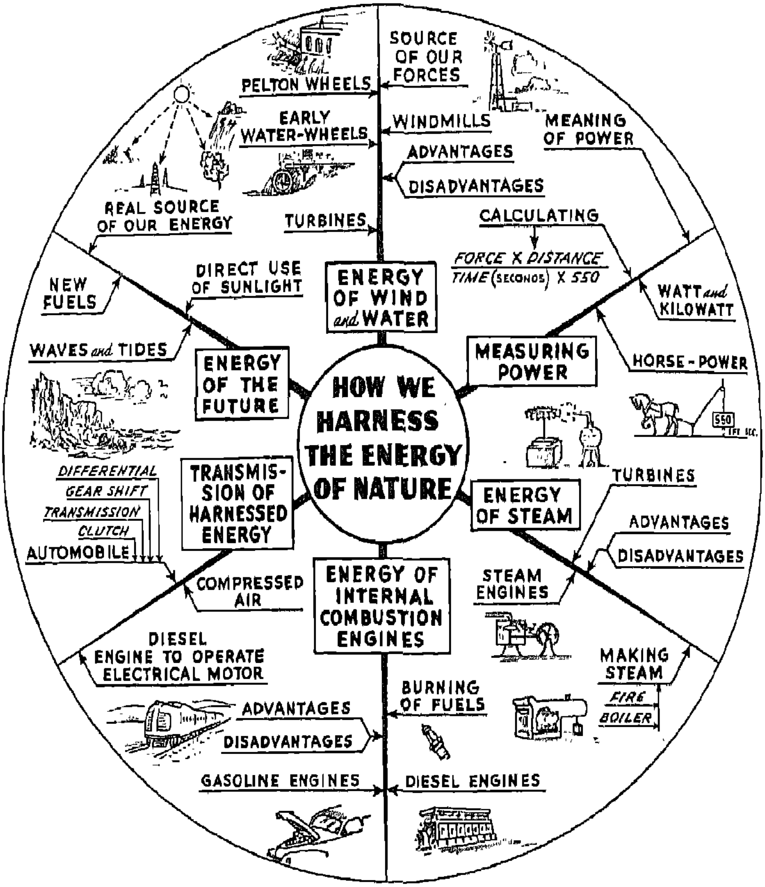


FIG. 15. GRAPH OF THE SUBJECT MATTER OF UNIT 9

Unit 5. The nature of energy, its forces and transformations.
Unit 6. How heat travels and is controlled.

Essential background material in *Book 3* includes:

Unit 4. The nature of work, its measurement and the use of simple machines.
Units 5 and 8. How electrical devices operate.

Knowledge gained in this unit on harnessing energy is significant in the consideration of some of the problems of conservation (Unit 12).

INTRODUCTORY EXERCISES (P. 496). *1. (*a*) Kinetic; (*b*) chemical (chemical potential); (*c*) potential (mechanical potential); (*d*) kinetic; (*e*) radiant; (*f*) chemical; (*g*) potential; (*h*) chemical.

*2. (*a*) By making some places warmer than others. Warmer air expands, becomes less dense, causes a difference of pressure and thus motion of air toward warmer places. (*b*) Shining on leaves helps them make food materials that are built into plants that form coal deposits. (Probably only coal forming today is in peat bogs.)

*3. Chemical energy of coal changes to heat and light.

*4. Evaporated from ocean by heat of sun, carried by wind to position over mountain, cooled, condensed, falls on mountain, runs into stream. More (potential) energy on mountain and so can do work going back to ocean.

5. Diagram need be only a simple section of dam, trough, or pipe to water-wheel, simple water-wheel or Pelton wheel.

6. Fire burns inside a furnace, hot gases come in contact with tanks or pipes of water that form boiler, heat conducted to water changes it to steam which has much pressure because of its expansion.

7. (*a*) Answer should include formation of steam, pushing of steam against pistons, control of steam ingo and outgo by valves, connection of pistons to driving wheels. (*b*) Energy comes from fuel burned in firebox.

8. (*a*) Turbine is an enclosed wheel with curved paddles, or blades, against which steam is directed to turn the wheel. (*b*) Has blades that rotate wheel directly rather than a piston that goes back and forth.

9. Carburetor mixes gasoline vapor in the correct proportion to explode. Spark plugs have gap between two wires where spark is formed to explode gasoline vapor. High-pressure gases from explosion push against pistons.

10. Fuel is ignited by air made hot by extremely high compression. Fuel squirted into cylinder by pump. No carburetor.

LOOKING AHEAD TO UNIT 9 (P. 497). Although this section in the textbook will require only a few minutes of reading time, the exploratory review and preview may well take an entire period. Questions and voluntary information from the pupils should bring to mind what they have already studied about work and energy and their uses. The material briefly presented in the printed preview should then be read and expanded and illustrated in discussion until the pupils begin to comprehend its real meaning.

Another plan for the preview would be to stress the historical changes that have occurred in man's harnessing of energy and the importance of harnessed energy in modern life. The pupils can then be asked to name all the machines that first turn the energy into useful forms, thus building up a list of the power machines to be studied. A later period can then be devoted to reviewing the forms of energy and their changes.

PROBLEM 1: HOW IS THE ENERGY OF WIND AND WATER PUT TO WORK? (P. 501)

Streams of moving air and water are harnessed in very similar ways; thus they are studied together in this problem. Although the number of windmills is greater than the number of waterwheels, the practical importance of the latter is far greater and should usually receive the greater emphasis. Local conditions and the interest of the class may call for a shift of emphasis in some classes. The main ideas brought out in Problem 1 are:

1. Wind and moving water possess much energy.
2. The main feature of any windmill is a propeller so shaped that the wind striking the blades forces it to turn; supplementary devices transmit the motion to the place where it is used.

3. The earliest harnesses for streams of water were wooden overshot and undershot water-wheels; both changed the energy of water into rotary motion.

4. A great deal of energy is now harnessed by modern types of water-wheels.

5. A Pelton wheel has curved "buckets" against which a nozzle directs a relatively small stream of water at high pressure.

6. In turbines a relatively greater volume of water flows through guide blades to turn a propeller.

7. Careful designing of modern water-wheels according to scientific principles has made them wonderfully efficient.

8. Most modern water-wheels are used to generate electric current whose energy can be used many miles away.

9. Although the energy of water is cheap, other disadvantages prevent the use of all available water power.

EXPERIMENT 47. HOW DOES A TOY WINDMILL WORK? (P. 504). The materials needed are as follows:

- Stick of soft wood (pine or balsa) ½ inch square, and 4 to 6 inches long
- Knife
- Large pin or slender nail
- Pencil with eraser (or a second stick of wood)

Boys who make model airplanes from balsa wood can make such a windmill very quickly. Some will be glad to construct a working model of an entire windmill. The propeller turns because the blades slope in opposite directions. Thus the wind tends to turn one to right and the other to left, and the propeller rotates.

SELF-TESTING EXERCISES (P. 506). 1. Answers may vary. Kinds of work most commonly done are pumping water and generating electric current. Sawing wood, grinding tools, grinding grain, etc., are other kinds of work that can easily be done.

2. Rotary motion is turning, circular, or round-and-round motion. Reciprocating motion is back-and-forth motion, usually in straight line but not necessarily so.

3. Response should include following essential points: (a) Windmill has propeller with two or more blades. (*b*) Blades set so wind strikes them at an angle. (c) Blades on one side pushed in one direction by wind and those on opposite side pushed in opposite direction. This causes propeller to rotate—gives it rotary motion.

4. Any one of several reasons may be given. (These reasons are, of course, the disadvantages of using wind for power.) (a) Wind does not blow steadily. (*b*) Mill to develop much power is impractical to build. (c) Windmills to be effective must be located on high places; they are easily damaged by storms. (It should be noted that a windmill has recently been built to generate enough electrical current to supply a town of 2000.)

SELF-TESTING EXERCISES (P. 511). 1. (a) Overshot and undershot (a special kind of undershot wheel was the breast wheel.) *b*) Pelton wheel and turbine.

2. Answers may vary. Differences that may be mentioned are: (*a*) Shape of wheels. (*b*) Pelton wheel has nozzle to guide water; turbine has flat guide blades. (c) Pelton wheels usually have horizontal shafts, while turbines are usually but not always vertical. (*d*) Turbines usually more efficient. (e) Pelton wheels operate best with small amount of water under high pressure; turbines opposite.

4. (a) Amount of water that flows through, (*b*) height from which water comes, (c) efficiency of the wheel.

5. Pupils may mention one or more of the following: (a) All surfaces along which water flows are smooth. (*b*) Flow of water is carefully guided along curved paths; passageways streamlined. (c) Water made to strike propeller blades at just right angle.

6. (a) Advantages that may be mentioned: (*1*) Low cost of energy. (2) Efficiency of machines. (3) Lack of smoke and fumes. (4) No store of fuel is being used up. (5) Water-wheels require few attendants—little labor.
b) Disadvantages that may be mentioned: (*1*) High cost of building dam and power plant. (2) Amount of water available depends on weather; therefore variable.

7. (a) Necessary plants would cost too much. (*b*) Much water power is far from any place where energy would be used. (c) Amount of water in most streams varies so much from time to time; therefore, not dependable.

PROBLEMS TO SOLVE (P. 512). 1. Opinions may differ but should be well supported. Most pupils will probably choose water power because of the large commercial power plants. Others may point to many small windmills and to fact that really it is wind power that raises water up and makes water power possible.

2. Advantages and disadvantages are mentioned in answers for Self-Testing Exercises 4, page 506, and 6, 7, page 512.

3. (*a*) 93,600 foot-pounds (62.4 × 10 × 150). (*b*) 84,240 foot-pounds (93,600 × .9).

4. Foot-pounds of energy available = 50,625 ÷ 90% = 56,250 ft.-lb. (*a*) Pounds of water falling = 56,250 ÷ 45 feet = 1250 lb. (*b*) Cubic feet of water = 1250 ÷ 62.4 lb. per cu. ft. = 20 cu. ft. (Either *a* or *b* may be accepted.)

PROBLEM 2: HOW DO WE MEASURE POWER? (P. 513)

Hazy ideas of the meaning of the term power and *horse-power* should be cleared up by the study of this problem. The scientific meaning of the term *work* and its measurement should be familiar to pupils when they begin the study of Problem 2. (See pages 217-220 of the text.) The story of the origin of the term *horse-power* adds interest and significance to the problem.

Enough numerical problems should be worked out to make sure that the pupils have grasped the answer to the main problem. If possible, the numerical problems should be ones brought in by the pupils and dealing with devices they know about. The main ideas brought out in the discussion of the problem are:

1. In one sense power is harnessed energy; in the other, it is the rate of doing work.

2. Units of power (in the second sense) are the horse-power, or 550 foot-pounds per second; the watt, or about 44 foot-pounds per minute; and the kilowatt, or one thousand watts.

SELF-TESTING EXERCISES (P. 517). 1. (a) Harnessed energy, kinetic energy, work, useful mechanical energy, or any similar term. *b*) Rate; do work.

2. *Horse-power* is rate of doing work; 550 foot-pounds per second or 33,000 foot-pounds per minute.

Watt is rate of doing work, approximately equal to 44 foot-pounds per minute.

Kilowatt is rate 1000 times greater than a watt. It is about 737 foot-pounds per second or about 1.34 horse-power.

3. To calculate number of horse-power a machine can deliver, one must know amount of weight machine can lift and distance it can lift weight in one second or one minute.

4. 99,000 foot-pounds in a minute (33,000 × 3).

5. 660 feet (33,000 × 10 = 330,000 foot-pounds of work the motor can do in one minute; 330,000 ÷ 500 = 660 feet the load can be lifted in one minute).

6. 8250 foot-pounds per minute (¼ × 33,000).

7. 3300 foot-pounds per minute, or 55 foot-pounds per second.

PROBLEMS TO SOLVE (P. 517). 1. Data will vary. If pupils are working from an understanding of problem to be solved, their methods of solution will probably vary. One method is as follows:

a) Total vertical height of stairs in feet × weight of person = number of foot-pounds of work done.

b) Number of foot-pounds of work ÷ number of seconds = number of foot-pounds of work done per second.

c) Number of foot-pounds per second ÷ 550 = number of horse-power. (In case of very large and strong boy running upstairs rate may approach one horse-power.)

2. .74 H.P. or about ¾ H.P. (550 ÷ 1000 = .55 kilowatt. .55 × 1.34 = .74 H.P. or almost ¾ H.P.)

3. (a) 1,650,000,000 foot-pounds per second (50,000 × 33,000). b) 37,500 gallons per minute (5280 × 8⅓ = 44,000 foot-pounds done in lifting one gallon of water a distance of one mile. 1,650,000,000 ÷ 44,000 = 37,500 gallons turbine could lift one mile in one minute).

PROBLEM 3: HOW DO WE USE STEAM TO HARNESS THE ENERGY OF FUELS? (P. 518)

In this problem some attention is given to the arrangement of fire and water for the efficient transfer of heat and to boilers as essential parts of steam power plants. The simple demonstration shown in Figure 471, page 522, should be clearly understood by pupils and compared with a more complex boiler and engine. With this basic and easily understood power device in mind, most pupils can work out the function of each essential part of a steam power plant.

In a similar way the simple steam turbine should be clearly demonstrated and understood. Then the modification for practical use should be discovered. If at all possible, the class should visit a power plant where boilers and engines or turbines are at work. In most cities municipal power plants or pumping stations may be visited. Often the local utility company will be glad to have properly supervised classes visit their power stations. Some time may well be given to the importance of steam power in the local community. The main ideas developed in the discussion of Problem 3 are:

1. Boilers are devices in which water can be changed to steam rapidly because a very large surface of water is exposed to metal heated by a fire.

2. In a steam engine, steam from a boiler presses against a piston in a cylinder and turns a wheel by means of a crank; supplementary devices let the steam in and out at the proper times and keep the wheel turning when the steam is not working.

3. In a steam turbine, steam from the boiler strikes one or more very carefully arranged rows of blades on a wheel and causes the wheel to turn much as the wind turns a windmill; steam turbines operate at terrific speeds.

4. Steam turbines are relatively more efficient than reciprocating engines, although neither one can use a very high percentage of the energy of a fuel.

5. Steam turbines have very definite advantages for some power uses but must be very skillfully made.

SELF-TESTING EXERCISES (P. 522). 1. Because it contains much stored energy (chemical energy).

2. (a) To heat buildings and (b) to produce steam for power. Latter use requires far more coal.

3. Main steps that should be listed are: (a) Burning of coal to

change chemical energy to heat; (*b*) Using heat to change water to steam; (c) Using steam to run some kind of engine.

4. For this exercise a diagram that shows a real comprehension of arrangement of water on one side of metal surfaces and hot gases from a fire on other side is preferable to a perfect copy of a textbook figure without understanding. Diagrams should be much simplified. Essentials are (a) space for fire, (*b*) passageways for gases, (c) water where it will be heated by gases, and (*d*) space for steam from boiling water.

5. Safety valve lets excess steam escape if pressure gets too high. It is essentially a perfectly fitting stopper, held in place by spring of proper strength or lever with weight on end.

SELF-TESTING EXERCISES (P. 526). 1. (*a*) *Piston.* Steam pushes it back and forth. (*b*) *Piston-rod.* Transmits push from piston to some other part, usually connecting rod. (c) *Crank.* Is pushed and pulled by force from piston and changes *back-and-forth,* or reciprocating, motion into rotary motion. (*d*) *Slide valve.* Lets steam first into one end of cylinder and then into other; lets steam out at proper times. (e) *Slide-valve eccentric.* Moves slide valve back and forth at proper times.

2. Answers will vary. Some differences are: locomotive is mounted on wheels, can move itself, has two pistons, carries its own boiler, cannot stop on dead center with both cylinders, etc.

3. Essential steps are as follows: (a) Coal containing chemical energy put in fire box of boiler. (*b*) Coal burned, changing chemical energy to heat. (c) Heat passed through boiler wall into water and changed it to steam. (*d*) Steam pushed against piston and moved it. (e) Movement transmitted to wheel and made it turn.

PROBLEMS TO SOLVE (P. 526). 1. Drawing should have parts of Figure 472, page 523, *changed as follows:* (*a*) *slide valve where* dotted lines show it, (*b*) steam entering right side of cylinder and leaving left side, (c) arrow above flywheel pointing left.

2. (a) Four times, twice from each cylinder. (*b*) Must be always in opposite position from what it would be to run forward. An example of one such reversed position is shown in dotted lines in Figure 472.

3. Most governors have two or more weights rotated by engine. Weights are attached to levers and through levers to valve in steam supply pipe. When engine runs rapidly, weights fly outward and

close valve to reduce speed. When engine slows down more than is desirable, weights are pulled in by springs and valve is opened to increase supply of steam and thus increase engine speed.

EXPERIMENT 48. HOW DOES A STEAM TURBINE WORK? (P. 528). Materials and apparatus needed are:

Large cork or cylindrical piece of wood
Blades cut from tin can
Tin shears
Glass tube
Large nail
Board for base
Flask to heat water in
Tripod or other support for flask
Wire gauze
Rubber stopper, one-holed, to fit flask
Glass delivery tube drawn to tip (as in Figure 476)
Water
Bunsen burner

The construction of the turbine for the class experiment should be carried out by a fairly skilled boy or the teacher, because of the need for reasonably accurate work to allow the wheel to run evenly. However, the construction and operation of additional turbines is a good project and may well be correlated with shop work. The teacher must be careful to supervise the use of the "boilers" because of the danger of developing too much pressure through carelessness.

SELF-TESTING EXERCISES (P. 531). 1. Driving rotating machinery that needs to turn very rapidly. Examples mentioned are cream separators, electrical generators, ship's propellers, centrifugal pumps.

2. After striking one row of blades on wheel, steam strikes row of stationary blades that turn it to strike second row of moving blades at correct angle. This plan is repeated over and over until most of energy of steam has been used.

3. (a) *Advantages (three called for)*: (1) Use less space for power they produce. (2) Run more smoothly. (3) More efficient —get more energy from steam. (4) Produce rotary motion without reciprocating parts. (5) Fewer parts and less friction.
b) Disadvantages (two called for): (1) Cannot be run slowly. (2) More difficult to make good ones. (3) Cannot be reversed.

PROBLEMS TO SOLVE (P. 531). 1. Some of problems that may be mentioned are: (a) What shape to make blades and nozzles to get most push out of steam. (*b*) How to fasten blades in wheels so they wouldn't fly out. (c) How to keep steam from getting past blades without striking them. (d) What materials to use for each part. (e) How many rows of blades to give best results.

PROBLEM 4: HOW IS THE ENERGY OF FUELS HARNESSED BY INTERNAL-COMBUSTION ENGINES? (P. 531)

To most people what goes on under the hood of an automobile is a mystery. Intelligent operation of a motor car depends upon an understanding of the underlying principles of the internal-combustion engine. The study of this problem should be directed toward that end as well as toward an appreciation of the place of internal-combustion engines in modern life. The problems of applying power from the engine to the wheels is taken up in Problem 5.

Every effort should be made to have the pupils examine real engines and parts so that their understanding of these power machines may be a real one. Motion pictures that show the cycle of operation are very effective. The main ideas are:

1. In internal-combustion engines a suitable fuel is burned in one or more cylinders; the hot gases push directly on the piston or pistons.
2. Burning of the fuel requires that it be vaporized and mixed with a suitable amount of air; carburetors (or injectors of Diesel engines) accomplish this end.
3. Ignition is accomplished by properly timed electrical spark or by heating the air by compression with the piston.
4. Very carefully arranged valves and other devices make each step in the engine's operation occur at the right time.
5. Special systems of devices provide the engine with fuel, keep it oiled, provide electricity, and keep it cool.
6. Internal-combustion power plants are usually lighter and more efficient than comparable steam power plants, especially in the smaller sizes.

EXPERIMENT 49. HOW DOES A MIXTURE OF GAS AND AIR BURN? (P. 533). Apparatus and materials needed are:

Specially prepared friction top "tin" can	Rubber tube
Large nail	Matches
	Gas supply

Where artificial gas or mixtures of artificial and natural gases are available, this experiment seldom fails. The flame is at first yellow, indicating that little air is mixed with the gas. It gradually becomes blue and smaller. The nature of the explosion is stated in the text.

Where gas is not available, the experiment may be done as a teacher demonstration with high-test, non-leaded gasoline:

Warm the can in a flame, remove the lid, and pour in 15 or 20 drops of gasoline. Place the lid on the can and shake the can up and down until the gasoline vaporizes and mixes with the air. Then bring a flame to the hole in the side. It may be necessary to experiment to find the exact amount of gasoline to give the correct mixture. Better results can sometimes be secured by adding a drop or two of ether instead of gasoline. If the mixture will not ignite at the top of the can, ignite it through the hole in the side of the can, being careful your fingers are not in line with the hole, because a flame may shoot out of the hole.

Some experimenting may be necessary to get just the right mixture of gasoline and air, but that only gives point to the necessity for careful carburetor adjustment. Use extreme care in handling gasoline to prevent an accidental fire. Carefully close the bottle each time a small amount is removed for use.

SELF-TESTING EXERCISES (P. 539). 1. Fuel is burned inside cylinder or cylinders of engine.

2. Which stroke is named first is of little importance, but clear thinking would call for the correct succession. More details about valve operation may be included but should not obscure the main function of each stroke.

a) *Intake* stroke. Piston moves away from end of cylinder, and mixture of gasoline and air enters.

b) *Compression stroke.* With valves closed, piston moves toward end of cylinder and presses mixture into much smaller space.
c) *Power stroke.* Electric spark causes fuel mixture to burn very rapidly; gases, expanded by heat, give very strong push against piston and give it much more kinetic energy.
d) *Exhaust stroke.* Exhaust valve opens, expanding gases rush out, piston moves toward end of cylinder and forces most of remaining gas out of cylinder.

3. The valve information may readily be presented in the form of a table. Pupils should be encouraged to think from function of each stroke to necessary positions of valves. Otherwise, the exercise is useless.

Stroke	What Is Happening	Intake Valve	Exhaust Valve
Intake	Taking in mixture of gasoline and air	*Open* to let mixture in	*Closed* to keep exhaust gases or air from entering
Compression	Compressing mixture	*Closed* to keep mixture from escaping	*Closed* to keep mixture from escaping
Power	Burning gases pushing on piston	*Closed* to make gases push against piston	*Closed* to make gases push against piston
Exhaust	Discharging burned gas	*Closed* to keep burned gases from going through carburetor	*Open* to let burned gases out through exhaust opening

4. Because heat produced by burning of fuel causes gases in cylinder to expand a very great amount.

5. Several cylinders give much more frequent pushes. Such an engine runs more smoothly.

Problems to Solve (p. 540). 1. In doing this problem, it is impractical to name each tiny part. Pupils should be able to recognize at least the following things "under the hood": motor block containing cylinders, pistons, and water spaces; spark plugs, distributor; spark coil; starter; generator; storage battery; radiator; water pump; fan; carburetor; air cleaner; gasoline line and fuel pump; horn.

3. (a) *Gasoline delivery truck:* (1) Does not suffer because of weather conditions. (2) Uses no fuel (or food) when not working. (3) Stands without hitching. (4) Can be backed more easily. (5) Runs more rapidly when long distances need to be covered, and in crossing streets, etc. (6) Does not leave unsanitary wastes on streets. b) *Horse-drawn truck:* (1) Drives itself from house to house while man is delivering. (2) Costs less in the first place. (3) Probably lasts longer. (4) Hauls better through heavy snow and mud.

4. (a) Two. (b) Four.

Self-Testing Exercises (p. 543). 1. (a) At end of compression stroke. (b) By means of powerful pump.

2. Compressing air in cylinders heats air above kindling temperature of oil.

3. Some differences between Diesel and gasoline engines (two are required): (a) Diesel engines usually heavier than gasoline engines that develop same amount of power. (b) Diesel engines burn cheaper fuel. (c) Diesel engines more efficient.

4. Reasons for use of internal-combustion engines rather than steam power plants in automobiles (three are required): (a) Usually lighter for equal power. (b) More efficient, especially in small sizes. (c) Can be started and brought to full speed quickly. (d) Do not require addition of water to make steam.

Problems to Solve (p. 543). 2. Main reason is weight. Diesel engines (and fuel) are much heavier than gasoline engines.

PROBLEM 5: HOW IS HARNESSED ENERGY TRANSMITTED? (P. 544)

The significance of this problem is clearly set forth in the first paragraph of the discussion. The transmission of energy is not only an extremely important process, but boys and girls must very frequently observe and manage devices which carry it on. The action of many such devices is so simple that the uninstructed can see how they work. Other devices, such as gears, belt pulleys, and levers are simple machines of the types studied in Unit 4. Discussed here are: (1) the automobile transmission because of its everyday use and as an example of what can be accomplished by a combination of simple devices, (2) the use of compressed air as a method of storing and transmitting energy, and (3) electrical transmission to associate electrical devices with prime movers and show how they are used in modern transportation.

The study of automobile transmissions should play an important part in developing intelligent drivers. For effective work a model of clutch and transmission should be available or the class should visit a display in a shop or salesroom where "cut-aways" of the real devices may be seen and operated. The main ideas of the problem are:

1. The harnessing of energy is not complete until it has been applied to the work that is to be done.

2. A series of devices transmits power from the auto engine to the drive wheels (rear wheels).

a) The clutch connects and disconnects the other devices by means of friction plates.

b) A series of gears, acting as wheels and axles, increase force and decrease speed, or the opposite, and reverse the direction of motion when necessary.

c) The differential allows the rear wheels to turn at different rates while the automobile is turning corners.

3. Compressed air serves as an effective transmitter of harnessed energy.

a) Energy is stored in the air by a compressor, or air pump.

b) The air passes to where it is to be used through pipes.

c) Special air-driven engines apply the energy to the work.

4. Systems of electrical generators, wires, and motors transmit much energy, not only from central power plants to homes and factories, but from the engines of trains and ships to the propelling devices.

SELF-TESTING EXERCISES (P. 548). 1. To disconnect engine from rear wheels so that car can be started and gears shifted.

2. To provide different mechanical advantages for changes in speed and force. Also to provide for reverse motion of car.

3. (a) Clutch pedal is pushed down to disconnect engine from

transmission gears by separating plate on flywheel from plate on transmission gears. (*b*) Gear-shift lever is moved (usually to the left and back) into low-speed position so that small gear on countershaft (which turns at same speed as engine) is connected with large gear on drive shaft. (*c*) Clutch pedal is allowed to come up, permitting clutch plates to come together again, thus connecting engine with transmission gears. (*d*) Countershaft turns drive shaft, and drive shaft turns rear wheels.

4. Motor would continue to run, but car would slow down and stop because clutch plates would be separated, thus disconnecting engine from transmission gears.

PROBLEMS TO SOLVE (P. 548). 1. Suddenly connecting running engine to car standing still exerts great force on gears, drive shaft, etc., because of inertia of rest of car.

2. Clutch, transmission gears, gear-shift lever.

3. One of recent changes is the so-called "fluid drive," in which the flywheel is replaced by two sets of vanes turning in oil.

SELF-TESTING EXERCISES (P. 551). 1. Uses mentioned in discussion are forming heads on rivets, setting brakes on trains, etc., sand blasting, pushing air out of caissons and tunnels. Other familiar uses are filling auto and bicycle tires, lifting cars for greasing, driving grease pumps, breaking concrete for street repairs.

2. Some power machine compresses air and stores energy in it; air flows through pipes to hammer and makes it work.

3. (*a*) Pump on locomotive fills large tank on locomotive and small tank under each car with compressed air. (*b*) Control valve between car tank and brake piston is kept closed when pressure is normal and locomotive tank and car tank are connected. (*c*) By letting air escape from pipe-line, engineer reduces pressure, which opens control valve between car tank and brake piston. (*d*) Compressed air from car tank passes through control valve into piston cylinder to exert force on piston, which "sets" brakes.

4. If train breaks apart or air-pipe breaks, compressed air in car reservoir turns control valve and automatically sets brakes to stop car.

PROBLEMS TO SOLVE (P. 551). 1. Air compressor is air pump usually worked by gasoline or steam engine. Piston in pump cylinder moved by engine so that it compresses air.

2. Compressed air is used in tunnels and caissons to keep water and mud out. Great danger is that workmen may get what is known as caisson disease, or "the bends," if they go in or out of tunnel or caisson too fast. Air lock is provided between outside and inside. In air lock, air-pressure is gradually increased or decreased as men go in or out. Caisson disease is caused mainly by bubbles of excess nitrogen forced into blood stream by higher air-pressure.

3. Pascal's Principle explains how liquids can transmit force: *A force applied to an area of fluid is transmitted undiminished in all directions to every equal area of a fluid.* This means that a pressure of one pound on a piston in a cylinder whose area is one inch can be transmitted to a piston in a cylinder whose area is 100 inches as a force of 100 pounds, thus giving a mechanical advantage of force.

SELF-TESTING EXERCISES (P. 553). 1. All common examples of use of electric current may be mentioned. Electric transmission in locomotives and ships are special examples.

2. (a) Engine or other power device being used drives a generator, (b) Wires carry current to one or more motors, (c) Motors turn wheels.

PROBLEMS TO SOLVE (P. 553). 1. Yes, in both cases. Motors or magnets could be arranged to do work. House trailers and street cars sometimes have magnetic brakes. (Any good reasons are acceptable.)

2. Any good answers should be accepted. The disadvantages mentioned might be original cost, complexity, specialized knowledge needed to repair, etc.

PROBLEM 6: WHAT SOURCES OF ENERGY WILL WE USE IN THE FUTURE? (P. 553)

Persons who feel some responsibility for the future welfare of the human race are seriously concerned about the fact that we are using up the supply of stored energy in fuels much faster than it is being formed. This whole problem is intimately tied up with the original source of almost all the usable energy on the earth. It is the purpose of this problem to point out the fact that most of our energy comes from one great source, the sun, and to set pupils wondering about the immediate sources of energy to be used when the supplies of coal and oil have been exhausted. The main ideas to be developed in the problem are:

1. Whether we harness the wind, running water, or the energy of fuels, the real source of the energy that runs our machines is the sun.

2. None of the supplies of energy now in extensive use seems to give promise of providing man with energy indefinitely; what the main supply will be in the distant future, we do not know; but scientists are already searching for an answer to this problem.

Self-Testing Exercises (p. 558). 1. (a) Radiant energy from sun changes to heat on earth. Some places are heated more than others, and differences of temperature cause wind to blow.
b) Heat caused by radiant energy from sun evaporates water. Wind caused as in (a) carries vapor to high places, giving it potential energy.
c) Radiant energy (light) from sun was stored in food made in green plants in form of chemical energy. Bodies of plants containing this energy were buried in earth and changed to coal.
d) Tiny plants or animals collected energy stored in food made by green plants. These tiny organisms were buried in sands deep in earth. Oil from these organisms collected in oil-bearing sand as petroleum.

2. No. Coal enough to last at least 1000 years, according to men who should know.

3. (a) *Wind.* Would require too many windmills and does not blow steadily enough. (b) *Water power.* Much is not close to where it is needed; not enough of it. (c) *Waves and tides.* Irregular and not close to all needs; not known how to harness them efficiently or store energy. (d) *New fuels.* No one fuel yet sufficient in amount to meet needs. (e) *Direct sunlight.* No known efficient way of using it; not available all the time. (f) *Atomic energy.* No practical ways of using it efficiently have yet been developed.

4. Because it is such a vast supply of energy. All usable energy really comes to earth in energy of sunlight. Using this energy directly would be more efficient.

Problems to Solve (p. 558). 1. (a) First steps are as in part b of Self-Testing Exercise 1. (b) Water running down toward ocean turned water-wheel. (c) Wheel turned generator. (d) Electrical generator made current. (*c*) Current flowed though bulb and produced light.

2. (*a*) As in Self-Testing Exercise 1, part c. (*b*) Coal burned as fuel to heat water and make steam. (*c*) Then steam turbine runs generator, which sends electric current to motor and makes it turn.

3. (*a*) As in Self-Testing Exercise 1, part *d*, until it comes out of ground in petroleum. (*b*) Petroleum distilled to get gasoline. (*c*) Gasoline goes into auto's tank, then into motor and is burned. (*d*) Released energy is passed along certain shafts and gears to rear wheels and drives car.

LOOKING BACK AT UNIT 9 (P. 558). 1. Fuels, running or elevated water, and wind.

2. (*a*) Fuels have been harnessed in two important ways: (*1*) by burning them to change stored energy into heat used to make steam to push against pistons of engines or blades of turbines and (*2*) by burning them in cylinders and letting expanded gases push against pistons.

b) Energy of running or elevated water is used by allowing it to push against cups or blades of some kind of modern water-wheel as water returns to ocean.

c) Energy of wind is harnessed by having it push against blades of windmill.

3. Mechanical, electrical, and by means of compressed air.

ADDITIONAL EXERCISES (P. 559). 1. (*a*) Steam pushed piston one way. Then steam inlet was closed, and cold water condensed steam. This produced vacuum on that side of piston. Atmospheric pressure then forced piston in other direction.

b) Watt arranged to admit steam to both sides of piston so that it could push in both directions. He arranged effective system of valves for admitting and releasing steam. Also arranged to condense steam in separate place so that cylinder was always kept hot.

c) At least two difficulties that were met in constructing early steam engines were (*1*) in making accurate cylinders and steam-tight pistons and (*2*) in controlling steam pressure in boilers.

d) Cylinder was placed vertically. Piston worked lever up and down. Lever was attached to crank on axle.

e) Similar to *d* except that axle turned paddle wheels.

2. Compound steam engines use steam twice by letting it push

against one piston and then leading it into a large cylinder where it can push against another piston connected to same crank shaft. This process may even be repeated in a third and larger cylinder.

3. In condensing steam engines, condenser is connected to exhaust pipe. Cold water or cold air flowing through pipes or openings around condenser keeps it cool. Steam condensing in cool condenser produces pressure lower than that in atmosphere and makes it easier for steam to push piston toward end of cylinder that is then connected to the condenser.

4. Modern carburetors are so complicated that little can usually be understood by examining only a whole carburetor. Reference books will explain much, and useful booklets and charts can usually be obtained by writing to carburetor manufacturers.

5. Parts which should be mentioned in this explanation and their uses are indicated below. Pupils can discover, in appropriate reference books, many interesting details about their operation.

Storage battery. To furnish current to spark coil and other parts.

Generator. Provides current to keep battery charged.

Timer. Breaks electric circuit from battery to coil just when spark is needed in cylinder.

Spark coil. Generates very high voltage and makes spark in spark plug when current flowing through it is suddenly interrupted by timer.

Distributor. Sends high-voltage current from coil to spark plug in cylinder that should have spark in it.

Spark plugs. Have gap between two wires to produce sparks when they receive high-voltage current from coil.

6. Super-chargers are air pumps which force more air into cylinders of internal-combustion engines than could otherwise be forced in and increase very greatly the power that engines can develop. Various types are described in reference books.

7. (*a*) Two. (*b*) Four. (*c*) Six.

8. (*a*) Larger number of parts that must be made, installed, repaired, and adjusted. (*b*) Greater difficulty in making all parts work together in right way. This includes balancing of crankshaft, timing of valves and sparks, and getting equal charges of fuel mixture into all cylinders.

9. A small expansible vessel is filled with a liquid that boils at desired water temperature. The end of this vessel is connected to a

valve in water system. Water is prevented from going to radiator when cold. When it gets warm, vessel is expanded by vapor inside it, opens valve, and lets water go to radiator of car.

10. Increases in pressure force water into air dome compressing air. Decreases allow air to expand and force water out. Air in dome thus acts as a cushion to smooth out pressure and prevent sudden shocks from causing damage to machinery.

11. Pressure increases boiling point of water about 2.5° F. for each pound per square inch of pressure, although increase is not strictly according to pressure. Thus, at 200 pounds per square inch of pressure water would boil at temperature above 700° F.

12. Superheated steam is steam heated hotter than when it left boiling water where it was formed. It is produced by leading steam through pipes that pass through fire or through hot gases from fire that heats boiler.

13. Type of engine invented by Corliss. Uses four rotating valves for a one-cylinder steam engine rather than single slide valve shown in Figure 472, page 523.

14. Uses are to drive projectiles from gun, break up rock and soil, blow soil and rock out of ditches, tear down buildings, etc. This question is debatable. Answer depends on interpretation of word harness.

15. Hydraulic ram uses power from large quantity of water to lift much smaller amount to higher level. Inertia of falling water operates it. Ram has outlet valve and valve into air dome. When water reaches certain speed, outlet valve closes. Force of moving water pushes water into air dome, compressing air. When speed of water slows down, outlet valve opens, and compressed air in air dome forces water from ram.

16. This exercise calls for a pupil diagram which can be worked out in a number of different ways. For instance, each "line" of energy could be illustrated with pictures cut from magazines or with well-drawn pictures by the pupil. This diagram is an excellent "organization" for the entire unit.

17. One of the important laws of science is Newton's "Third Law of Motion": *To every action there is an equal and opposite reaction;* that is, when a bullet leaves a gun in one direction, the heavier gun must "kick" in the opposite direction, but more slowly. In rotating lawn sprinkler water is thrown out sidewise from open-

ings. Openings are on projecting tubes that are free to move. As water shoots out in one direction from these arms, arms are pushed opposite way and rotate.

18. Exhaust noise is due to sudden puffs of exhaust gas when exhaust valves open. Muffler causes puffs to go through many crooked and irregular passages so that they are reduced to a more nearly steady flow and do not make a loud noise when they reach the air.

19. By means of their connecting rods, all the pistons are fastened to a single crank. Each piston gives a push at a different place in the crank's revolution.

20. (a) Any combustible dust suspended in the right amount of air to burn it will explode when ignited. Each particle burns very quickly and sets fire to its neighbors and burning spreads very rapidly. Heat expands air and gases from burning material and causes explosion damage. Powdered sugar, starch, flour, grain dust, coal dust, etc., cause explosions. Powdered coal has been used to run Diesel engines. (b) Conditions are very similar to those in an auto engine: finely divided combustible material, mixed with correct amount of air, ignited by some means. The one condition that is lacking is compression of mixture.

BULLETINS AND PAMPHLETS FOR UNIT 9

Farmers' Bulletin No. 1658. *Farm Water Power.* 5c
Navy Department, Bureau of Engineering
  Diesel Engines. 10c
  Reciprocating Steam Engines. 15c
  Turbines. 15c

VISUAL MATERIALS FOR UNIT 9

MOTION PICTURES

Encyclopaedia Britannica Films
"Water Power"
"Four-Stroke Cycle Gas Engine"
"Steam Power"
"Energy from Sunlight"
"Energy and Its Transformations"
"Fuels and Heat"

How Do We Improve Plants and Animals?

FUNCTION AND SCOPE OF UNIT 10. Needless to say, the material of this unit is of tremendous practical importance; it also possesses a very natural and unforced interest for the pupil. One evidence of the widespread appeal of material on this subject is the fact that a magazine of decidedly popular character has run a series of long articles on Luther Burbank and his work.

While it is of course practically impossible in the classroom or laboratory to show by demonstration or experiment the workings of the laws of heredity, the everyday surroundings of the pupils furnish abundant evidence. The farm, of course, is itself a laboratory. But every home with a garden, either vegetable or flower, and every home with animal pets provides material for illustration. Every food plant that man grows and every animal he uses has an interesting history of improvement. Not least in importance are the pupils themselves and all the races and nations of the earth.

A teacher who is tactful and thoroughly informed can render valuable service in clearing up misconceptions and allaying groundless fears arising from ignorance and half-knowledge regarding the effects of heredity.

INTRODUCTORY EXERCISES (P. 562). 3. Selection of best seed or offspring is commonest method of improving. With animals selection of female and male with desirable qualities is commonly used.

*4. Seeds, runners, spores, regeneration of missing parts.

*5. Transfer of pollen from stamen to stigma of pistil. Brought about by wind, water, insects, and by organism itself.

*6. Fertilization takes place when sperm unites with egg cell. Prerequisite to growth. Also secures transmission of characteristics of both parents.

7. That his nose is similar in shape to his father's nose.
8. They are selected animals secured from long line of breeding.
9. May be sweeter, larger, prettier in color, juicier, etc.
10. By grafting.

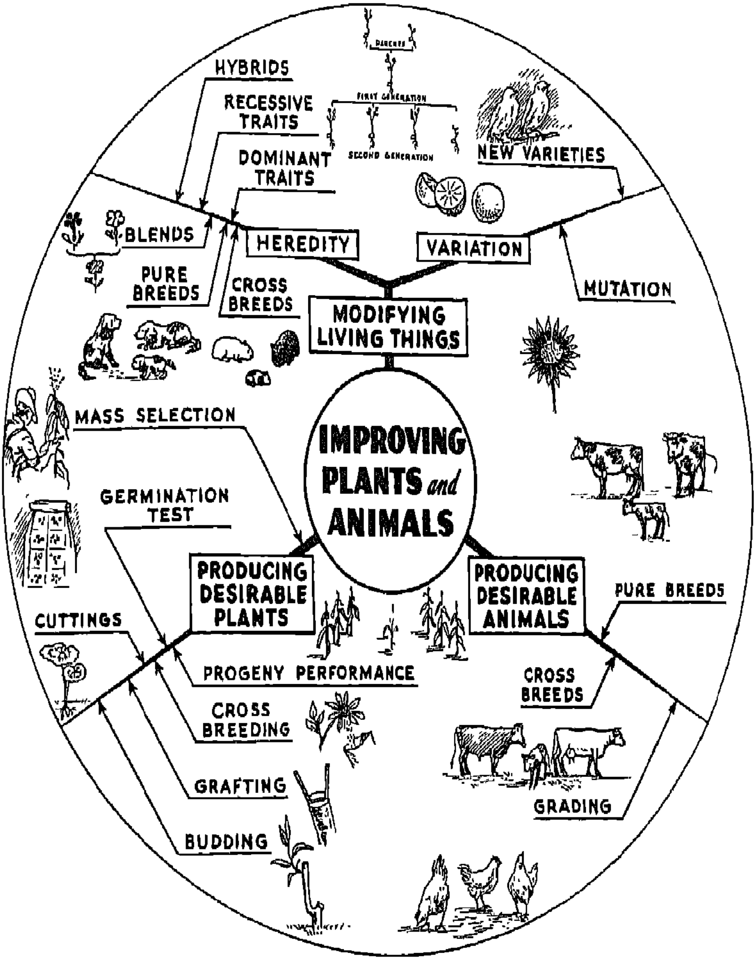


FIG. 16. GRAPH OF THE SUBJECT MATTER OF UNIT 10

11. *Improving animals:* Crossing two parents with different characteristics, selection of parents with desirable characteristics, selection of offspring. *Improving plants:* Cross-pollination of desirable species and selection of plants for seed.

LOOKING AHEAD TO UNIT 10 (P. 563). This overview shows that improvements in plants and animals have been made by man and that these improvements are the result of study and experimentation. Pupils may be asked to describe the wild ancestors of plants they have seen, and these may be contrasted with the domesticated varieties. From this contrast pupils should see the kinds of improvements that have been made. Pictures of the wild ancestors of domesticated animals may also be used in this manner.

A discussion of the social and economic significance of man's improvement of living things would also be very desirable. For example, varieties of corn and wheat have been developed that will mature in regions far north of the natural habitat of these plants. Pigs, sheep, and cattle furnish more meat than ever before in the history of mankind.

PROBLEM 1: WHY ARE OFFSPRING LIKE THEIR PARENTS IN SOME WAYS AND DIFFERENT FROM THEM IN OTHER WAYS? (P. 566)

This is a very important problem. It answers many of the questions that pupils have about themselves. The treatment is as elementary as it can be made and still get across some of the essential ideas. This same unit will, of course, be studied again in biology; but since many pupils do not study biology, the present material may constitute terminal education in this field. It should be emphasized that heredity has been fairly well explored by the scientist and that the principles formulated by scientists explain many facts of heredity very well. Following are the major ideas of the problem:

1. Children or offspring tend to resemble their parents; this tendency is called heredity.

2. Children of the same family may differ in certain characteristics from either father or mother because they inherit characteristics from both father and mother.
3. In cross-breeding, characteristics from both parents for the same trait are brought together.
4. Some characteristics (the dominant) for a trait hide other opposite characteristics (the recessive) for the same trait.
5. The recessive characteristic is not lost when plants or animals are cross-bred; it may appear in a later generation.
6. Plants or animals that contain both the recessive and the dominant characteristics for a trait will not breed true; they are hybrids.
7. Only plants or animals in which the characteristics for a trait are of the same kind (both dominant or both recessive) will breed true.
8. Sometimes one characteristic for a trait is not completely dominant over another, and the result is a blend.
9. Children of the same family may differ because the inheritance of the characteristics for each trait may be mixed.
10. Differences in living things of the same species are called variations.
11. New traits, called mutations, sometimes appear suddenly and will breed true; many of these produce desirable new traits which man perpetuates.
12. Inheritance determines kind of body and brain you start out with; it does not determine kinds of uses to which you may put your inheritance.

Self-Testing Exercises (p. 569). 1-4. Answers will vary. Summary of results found in class as a whole will be interesting. Results will show that no rule can be set up to predict what characteristics will be inherited from father or from mother.

5. Tendency of offspring to resemble their parents.
6. Because they inherit characteristics from both.

Self-Testing Exercises (p. 575). 1. (a) Pollen from one plant is transferred to stigma of another plant. (b) Because each parent has its own characteristics.

2. Diagram should show: (*a*) all black offspring from mating of black and white. (*b*) One fourth white and three fourths black offspring from mating of two hybrid black offspring. Assuming four offspring, one black will breed true, two will be hybrids, and the white will breed true.

3. Because the recessive trait may express itself.

4. Blend or intermediate characteristic.

PROBLEMS TO SOLVE (P. 576). 1. By self-pollinating it through two generations.

2. Select plant with recessive character in second generation.

3. Self-pollinate plants showing dominant character. Save seed from line of plants that shows no recessive offspring.

SELF-TESTING EXERCISES (P. 580). 1. Parents may have different traits. One trait may be dominant over other, or they may blend.

2. Each trait can be thought of as a unit characteristic, and its inheritance is not related to inheritance of other characteristics.

3. Differences in living things of same species. One reason is that living things inherit characteristics from both father and mother.

4. New trait that appears suddenly and that is inheritable. Hornless calf, red sunflower, etc., are examples.

PROBLEMS TO SOLVE (P. 581). 1. No two leaves will be found exactly alike.

3. Concerned with characters that already existed in parents.

5. Finger-printing, cephalic index (a number computed from certain measurements of head), kind of hair, kind of blood, etc.

6. Beardless wheat, seedless orange, most double flowers, white canaries, etc.

7. Present as recessive character in preceding generation.

SELF-TESTING EXERCISES (P. 584). 1. Physical characteristics and brain capable of certain degree of development.

2. Ability to speak languages; musical skill, diseases.

3. Environment affects use individual makes of his inheritance.

4. Need also to acquire good habits of using one's brain.

PROBLEMS TO SOLVE (P. 585). 2. Tuberculosis was often transmitted from parent to baby after birth because of ignorance of cause of, and protection against, the disease.

4. No. Each individual must learn to associate the elements of behavior necessary for the habit.

PROBLEM 2: HOW ARE DESIRABLE KINDS OF PLANTS PRODUCED? (P. 585)

This problem provides a basis for understanding how our plants have been improved and has practical implication in the raising of plants at home. Experiments with cuttings and grafts can be tried. Use of the new root-forming hormones make it possible to carry on experiments requiring but a short time.

To pupils living on farms many of the basic ideas of the problem will be familiar, and such pupils should be able to furnish practical examples of methods and results. All pupils will find it interesting to "read up" on the origin and development of our domestic plants. Any good encyclopedia will give fascinating stories of wheat, cotton, corn, and other plants that we use.

If the teacher so desires, he may well elaborate the line of thinking suggested in the opening of the problem, pages 585-586. Malthus was quite correct when he predicted that population would exceed the available food supply. His prediction was sound on the basis of facts then at hand. No one could foresee the beginning and development of scientific agriculture.

Following are the major ideas of the problem:

1. Plants may be improved by mass selection and by progeny performance; the latter method is more difficult, but it is more successful.
2. Plants may be improved by cross-breeding plants with desirable characteristics.
3. Desirable plants may be perpetuated by cuttings and grafts.

SELF-TESTING EXERCISES (P. 591). 1. Because seed is selected individually from plants that have produced good seed.

2. Test tells percentage of seeds from a given sample that will germinate; thus test shows whether or not the selected seed has a high germination rate, that is, how many plants you may expect to get from a given quantity of seed.

PROBLEMS TO SOLVE (P. 591). 1. Either the mass-selection or the progeny-performance method can be used.

2. Answers will vary. Pupils may write to seed companies, such as advertise in garden magazines, for further information.

SELF-TESTING EXERCISES (P. 596). 1. Removes stamens from flower of one kind of plant to prevent self-pollination. Then covers pistil with paper bag. Pollen from other plant is later dusted over this pistil, and bag again put over pistil.

2. Each parent has different characteristics. Offspring will be a mixture of these various characteristics.

PROBLEMS TO SOLVE (P. 596.) 1. No. Through cross-breeding and selection he perpetuates plants with desirable characteristics.

2. Burbank produced hybrids and by long selection developed them into plants that bred true.

SELF-TESTING EXERCISES (P. 599). 1. Cutting is taken from plant and placed in ground, where it develops new root system. Graft is taken from one plant and placed on another plant so that it will grow there.

2. Budding is a special kind of grafting in which buds are removed from one plant and transferred to another plant; ordinary grafts are made by placing a piece of mature stem in a cut in another stem or in a root.

3. They can propagate plants that cannot otherwise be made to breed true.

PROBLEMS TO SOLVE (P. 599). 1. It is the cells in the cambium layer that grow. Probably more important is the fact that this position brings together in proper relation the tissues that carry water up and food down.

2. Graft scions of desirable tree on undesirable tree.

PROBLEM 3: HOW ARE DESIRABLE KINDS OF ANIMALS PRODUCED? (P. 600)

This problem continues the discussion of the improvement of living things by breeding and selection. The treatment is very elementary, being designed primarily to orient the pupil toward the problem of animal breeding and to acquaint him with terms frequently encountered in popular reading. To many pupils in rural areas the material of the problem will be quite familiar. Some pupils in city schools will have acquaintance with thoroughbred pets, especially cats and dogs.

As with Problem 2 in the case of domestic plants, there is, if the teacher desires to make use of it, much interesting material on how man has improved his domestic animals. Encyclopedias give the story of such animals as the Hereford, the Jersey, and the Holstein cow, the Cotswold, Rambouillet, and Merino sheep, the Hampshire, Poland-China, and Duroc hog, etc.

Following are the major ideas of the problem:

1. Pedigreed animals are the product of continuous selection of animals with desirable characteristics over a long period of time and where ancestry is recorded.

2. The offspring of pedigreed animals are likely to be better than the offspring of mixed stock.

3. Animals may be improved by using a pure-bred sire with a dam that is not pure-bred; this method is known as grading.

SELF-TESTING EXERCISES (P. 604). 1. One whose ancestry on both sides has been recorded for many generations.

2. Grading.

3. *Pure-breeding:* Both father and mother are pedigreed animals. *Grading:* Father is a pedigreed animal; mother is not. *Cross-breeding:* Father and mother may or may not be pedigreed. Basis of choice is desirable characteristics they possess.

LOOKING BACK AT UNIT 10 (P. 605). 1. In general, this should include most of the major ideas listed in this *Guidebook* at the beginning of each problem, pages 236, 239, and 241.

3. *Heredity:* tendency of offspring to resemble parents.

Cross-breeding: crossing two varieties of plants or animals with different characteristics.

Breed true: given trait will be same as in parent.

Mass selection: selection of best plants or animals of given generation for sowing seed or for breeding.

Scion: twig that is to be placed on another plant in grafting.

Sire: father.

Trait: characteristic.

Blend: produced when one trait is not completely dominant over other.

Hybrid: plant or animal containing both dominant and recessive characters for same trait.

Stock: plant on which a graft is made.

Dam: mother.

Inheritance: traits passed on from parents.

Dominant trait: trait which appears and hides its opposite when the two are crossed.

Progeny performance: selection of desirable plants or animals by keeping a record of success of their offspring.

Pure-bred animal: animal whose ancestry has been recorded over a long period of time and is known not to have been crossed with other varieties.

Variation: differences in living things of same species.

Recessive trait: weaker trait that is suppressed by dominant trait.

Mutation: sudden appearance of new trait.

Grafting: transferring part of one plant to part of another plant where it will grow.

Grading: breeding pure-bred sire with dam that is not pure-bred.

ADDITIONAL EXERCISES (P. 605). 3. Animals produce fewer young; thus the process is much slower and much more expensive.

6. Grapefruit originally brought to Florida from West Indies. A seedless variety called Marsh Seedless originated from an ordinary tree, probably by a bud mutation, and was propagated by budding. Mutation occurred in a Marsh seedless, producing some fruit having pink flesh. Buds from branch having pink fruit propagated this strain, called the Thompson variety. On a Thompson tree in Texas a mutation occurred giving fruits with pinkish skin and deeper red fruit. This strain called Ruby grapefruit. (See Agricultural Yearbook for 1937 for account of citrus fruits and origins of varieties.)

12. (a) 16 (2^4). (b) 268,435,456 (2^{28}). (c) From the large figure in part b, it is clear that the answer to part c will be enormous.

BULLETINS FOR UNIT 10

Agriculture Bulletin No. 974. *Directions for Blueberry Culture* (1921). 30c

Agriculture Circular No. 528. *New Chrysanthemums* (1939). 5c

Agriculture Yearbook Separates

No. 1567. *Better Plants and Animals.*

No. 1585. *Improving the Wild Blueberry.* 5c

Farmers' Bulletins

No. 1167. Essentials of Animal Breeding (Rev. 1924). 5c
No. 1443. Dairy Cattle Breeds. 5c
No. 1567. Budding and Grafting.
No. 1779. Beef Cattle Breeds for Beef and for Milk. 5c

VISUAL MATERIALS FOR UNIT 10

CHARTS

Extension Service

Educational Illustrations, Group 1 (A 43.22), "Livestock." Set of seven charts. 25c

MOTION PICTURES

Society for Visual Education

"Dairy Cattle and Their Selection"
"Dairy Cattle—Types, Breeds, and Characteristics"

UNIT 11

How Have Living Things Developed on the Earth?

Function and Scope of Unit 11. The educational experiences of a well-rounded person should include some acquaintance at least with scientific ideas as to the development of living things. These ideas give the individual a better perspective by showing the relationships between the past and present. Undoubtedly, a better idea of the time sequence of present-day happenings can be built upon the understanding of the great physical events of the world's history with its corresponding events in the history of plants and animals.

Furthermore, the earth and the living things on it are now known to be constantly changing rather than static and unchanging. Adjustment to things as they really are requires that pupils grasp this reality. The earlier study of geological changes has, for most pupils, brought out the kinds of change that take place on the earth's surface and within it.

This unit attempts to present in a simple, straightforward manner (1) the story of the physical changes that have happened to the earth in the geologic past, and (2) the story of the kinds of plants and animals that have inhabited the earth at different times in the earth's history. Much stress has been placed upon the methods used by scientists in unraveling this complex story, and certainly there is no greater tribute to man's intellect than the development of this story of the past. Consequently, at all times during the teaching of this unit emphasis should be placed upon the methods which scientists have employed in reaching their conclusions.

The story of the development of living things upon the earth is based upon fossil records, comparative embryology and anatomy, the classification of organisms, blood tests of animals, and the geographic distribution of plants and animals over the earth. Unit 11 draws upon these different fields for material which is grouped about the various problems in such a way as to give continuity to the whole. Earlier units in the *Science Problems*

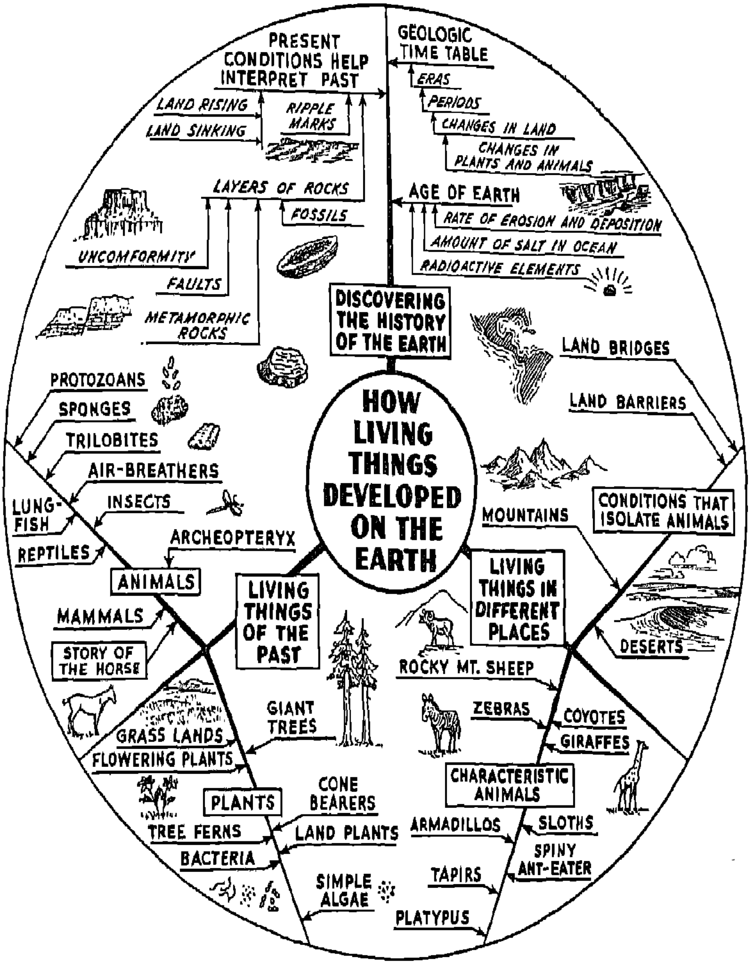


FIG. 17. GRAPH OF THE SUBJECT MATTER OF UNIT 11

series provide a helpful background for the study of this unit. These units are those on the earth's surface, on reproduction and development (*Book 2*, Units 3 and 10), on classification and improvement of plants and animals (Units 2 and 10 of this book). The teacher should be prepared to review this material, if already studied, or to supplement the present unit if adequate background is lacking.

INTRODUCTORY EXERCISES (P. 608). 1. (*a*) Many millions of years. (Actual estimates are two thousand million years at least.) *b*) By estimating rates of erosion and deposition to form rocks, rate of deposit of salt in ocean, and rate of change in radioactive elements (such as uranium) in rocks.

*2. In bodies of water that have no outlet, minerals remain in water and make it salty. Minerals can neither evaporate nor be taken to other places. They accumulate and make the water salty.

*3. Rocks broken up by weathering, roots, plants, animals, chemicals, etc. Moving water, wind, and ice grind up rock and carry it away. Mountains worn down.

*4. Sand, clay, and other eroded materials carried and deposited by water, wind, etc., in layers. Top layers press on bottom layers. When they are covered with water, minerals in solution in water pass down through sand and clay; crystals of these minerals fasten clay or sand particles together. Rocks are thus formed by combination of pressure and cementing effect of minerals.

*5. (*a*) "Fire-formed rocks," that is, rocks formed by melting and hardening of rocks in interior of earth.
b) Metamorphic or, "changed," rocks are sedimentary rocks changed to other forms such as slate and marble under great heat and pressure far down in earth.

6. (*a*) Remains of plants and animals often found in sedimentary rocks.
b) (*1*) What kinds of plants and animals formerly lived on earth. (*2*) Relative ages of rocks in which fossils were formed. (*3*) What kinds of climates there must have been in different parts of earth. (*4*) What surface of earth was like in past.

*7. (*a*) Elements that give out heat energy all the time as they change into other substances. (*b*) Radium, uranium, thorium, actinium.

8. (a) Climate changed; vegetation changed and couldn't get proper food.
b) Enemies increased.
c) Conditions became unfavorable for reproducing and not enough young produced to carry on race.
d) Bodies not adapted to changing environment. Too big and heavy to catch smaller animals for food.

9. Slight changes or mutations occur in animals over periods of millions of years. Some valuable for survival, others harmful. Animals with valuable mutations better adapted. Live and reproduce. Other animals die out. Gradually new race developed.

10. These animals developed in places where they are now found, and barriers of one kind or another have kept them from spreading to other regions.

11. (a) *Plants:* Thallophytes (algae and fungi), Bryophytes (mosses and liverworts), Pteridophytes (ferns and their relatives), Spermatophytes (seed plants).
b) *Animals:* Protozoa, echinoderms, coelenterates, annelids, mollusks, arthropods, vertebrates (fish, amphibians, reptiles, birds, mammals).

LOOKING AHEAD TO UNIT 11 (P. 609). Almost any environment has some outstanding geological feature which may be used to stimulate interest and thus provide a starting point for this preliminary outlook upon the unit. If such a feature is available, make use of it in introducing these pages. For example, a fossil print of a fern in a piece of coal might be used. Some such statement as the following would serve to catch the immediate attention of the pupils: "Here is the print of a fern in a piece of coal. Many millions of years ago, this, and other strange kinds of plants, grew in moist swampy places. Many of these plants have formed the coal which we use today. This fossil print is good evidence for showing us what kinds of plants lived then. Read the material on pages 609-611 for beginning the study of what has happened upon the earth in the past." Following some similar discussion, the material on these pages may be read silently in class and class discussions based upon the reading.

The idea of the long sweep of time before written history will have to be introduced here to get the pupils to begin thinking in terms of geologic time. Undoubtedly, such picturesque and unusual animals as dinosaurs and the strange landscapes which existed when these animals lived will arouse a great deal of interest. Also, from advertisements and other common materials most pupils will have gained some familiarity with these animals which will aid in the introductory discussions. A review of page 169 of *Science Problems, Book 2*, will probably prove of value at this point. Two outstanding ideas which provide an insight into the entire unit are: (1) Scientists want to know how living things have changed since they first appeared upon the earth; so they study the fossil remains found in rocks. (2) Different kinds of fossils are found in different layers of rock; thus, estimating the ages of these layers of rock provides a knowledge of the time when the animals actually lived upon the earth.

PROBLEM 1: HOW DO GEOLOGISTS DISCOVER THE HISTORY OF THE EARTH? (P. 612)

Two outstanding ideas in this problem should receive special stress, since they are not usually incorporated in the thinking of pupils at this level: (1) the tremendous span of geologic time in comparison with the average life-span of human beings, and (2) the state of slow but constant change of the earth in which large-scale events take place. It is often difficult even for adults to understand the gigantic scale of time and change, since the average person tends to estimate these great factors in terms of the human life span. Consequently, the development of these ideas will have to begin with this first problem of the unit and continue throughout its duration if the pupils are to grasp these ideas.

The rich variety of materials of this problem makes desirable the use of actual specimens whenever it is at all possible. Specimen collections of igneous, sedimentary, and metamorphic rocks, rocks containing ripple marks or other geological indications, fossil shells, bones, teeth, coal prints, or amber containing preserved specimens all contribute toward making the unit real to the pupils. Of course, as many of these suggested materials as are available locally should be collected by teacher and pupils and brought to the classroom for study. In regions which are lacking in such materials, inexpensive sets of fossils and other similar collections which are provided by scientific supply houses will prove of greatest value in enlivening the study. Again, there is no substitute which quite takes the place of first-hand experiences.

Something which is not directly mentioned in the text but which is of extreme importance in the proper presentation of this problem (the entire unit for that matter) is an acquaintance with the geological history of the local environment. The teacher should, as a part of his preparation for this unit, become familiar with the local geologic history and know where any outstanding geologic features or specimens can be seen. State geology departments usually have many maps, bulletins, and other valuable materials which will prove very helpful to both teacher and pupils.

The title of the problem indicates that the emphasis is to be placed upon the kinds of evidence that geologists have used in discovering the history of the earth. Table 6, page 626, is planned to show the sequences of events, both physical and biological, as they have been developed from the evidence presented in the problem. Much use should be made of the Table 6, since it forms the basis for understanding geologic history. An enlargement of this table made by the pupils and filled in during the study of the problem is a valuable teaching device. The main ideas of the problem are:

1. Slow but constant geologic processes are changing the earth today just as they have in the past.

2. The study of rocks enables geologists to interpret the earth's history.

a) The materials of which rocks are made tell something of the ways in which they were formed.

b) The way layers of rock lie in relation to each other helps tell the history of the earth.
c) Fossils show some of the kinds of plants and animals that have lived in the past and the conditions under which these living things existed.

3. (a) The longest divisions of geologic time are known as eras.
b) Eras are separated into shorter divisions of time known as periods.

4. Some of the ways in which geologists estimate the age of the earth are: (a) The rate of erosion and deposition of materials.
b) Estimations based upon the per cent of salt in the oceans.
c) The disintegration of radioactive elements in the earth.

SELF-TESTING EXERCISES (P. 616). 1. (a) Holes bored by sea animals in temple columns on coast near Naples show temple was once under water. (*b*) Marks cut in rock near water by Swedish fisherman are now several feet above water. (*c*) Paved streets of Swedish town are now under water. (*d*) Islands in New York Bay are tops of hills. (*e*) Fossils of sea animals found in mountains high above present sea level.

2. Answers will vary but should contain the following idea: Since the same kinds of changes occurred in the past as are taking place now, we can tell what must have happened in the past by studying what is happening at present on the earth.

PROBLEMS TO SOLVE (P. 616). 1. Most changes take place so slowly they are not noticeable.

SELF-TESTING EXERCISES (P. 619). 1. (a) Tiny pieces of quartz deposited by wind or water. Layers accumulated and combination pressure and cementing effect of mineral crystals formed these into rock.
b) Shale formed in same way from mud.
c) Limestone formed in same way chiefly from shells and skeletons of sea animals.

3. Some tremendous force broke the rocks and moved them along past each other.

4. (a) Changes that have taken place in earth's surface. (*b*) How these changes probably took place. (*c*) Relative ages of different layers of rock.

SELF-TESTING EXERCISES (P. 623). 1. They decay.

2. Sedimentary materials such as clay, sand, and lime-mud are usually materials that cover bodies of dead animals and plants. Great heat which melts material to form igneous rocks would also melt even hard parts of plants and animals.

3. (a) *Preserving in ice.* Mammoth frozen into ice so that whole animal was preserved for thousands of years.
b) *Petrification.* Body or part of body changed to stone. Petrified trees found in some places in the western United States.
c) *Formation of a mold.* Animal or plant becomes buried and soil around will harden. Body decays leaving mold that looks like animal or plant. Mold later fills with minerals that will harden and have shape of original animal or plant.

4. (a) *What surface of the earth was like.* Sea animals found in places that are now far from sea.
b) *What climate was like.* Plant remains show that many places that are cold now were once very warm.
c) *What kinds of plants and animals lived on earth.* Bones, shells, molds, imprints, etc., tell us what plants and animals were like.

5. Each different division of geologic time contains fossils that appear only in that division. If some of these fossils are found in a new region, they indicate age of rock in which they are found.

SELF-TESTING EXERCISES (P. 628). 1. Era is longest division in earth's history. Periods are shorter divisions of time into which eras are divided.

2. By means of unconformities or breaks in the record that are great enough to be found all over earth.

3. There are intervals between eras in which great changes in earth took place. Mountains formed, volcanic activity occurred, erosion, etc. Geologic record in rocks has been destroyed so that we cannot tell how long eras were.

4. Because table corresponds to way rock layers are found in earth, with oldest at bottom and newest at top.

SELF-TESTING EXERCISES (P. 632). 1. (a) *Speed of building up of land.* Have estimated how long it takes to build up one foot of rock. Dividing thickness of rock by rate of formation gives age of sedimentary rock.
b) *Analysis of amount of salt in ocean.* Found out how much salt is added to ocean each year. Estimated total amount of salt in ocean.

Dividing this amount by amount added each year gives approximate age of earth.

c) *Changes taking place in igneous rocks.* Radioactive elements undergoing change to form lead and helium at a definite rate that is always constant. Sample of rock containing uranium is found. Amount of unchanged uranium compared with amounts of lead and helium present. By means of mathematical formula, age of rock determined.

2. Method in part c. Rate of change of uranium is always same and is not influenced by outside conditions.
3. At least two billion years old.

PROBLEM 2: WHAT HAVE GEOLOGISTS LEARNED ABOUT THE LIVING THINGS OF THE PAST? (P. 632)

This problem provides material for filling in to a greater extent the skeleton outline of geologic history that was introduced in the previous problem. During the study of this part of the unit, constant reference should be made back to Table 6, page 626, or to the enlarged outline of this chart that was made by the pupils (suggested earlier in the teaching suggestions for this unit).

The story of living things of the past is introduced with the history of the development of a single animal, the horse. The story of this animal's development is used because it has probably been more completely worked out than that of any other animal. Also, the remarkable changes which have been experienced by this domestic animal never fail to arouse interest on the part of the pupils.

The story of the development of the horse is followed by tracing some of the outstanding events in the long succession of animals beginning with the earliest kinds and proceeding to the present. In addition, the story of the development of plants is presented as paralleling the development of animals. When the idea of mutations on page 635 is presented, the class should refer to pages 579-580. The part played by mutations and adaptations in enabling species to survive should be carefully developed.

The last paragraph on page 647 contains a very brief summary of the important principles underlying the development of plant and animal life. Summary discussions should be held at the end of the study of this problem to bring out these points in relation to both plants and animals. The main ideas to be presented during the study of this problem are:

1. The history of the horse illustrates how a group of animals survived because they became adapted to changing environmental conditions.

2. Slight mutations appearing from time to time in a group of animals result in a very different group many thousands of years later (mutations are capable of being passed on from generation to generation and some of them aid in adaptation to changing environments).

3. Some important events in the development of animal life have been the appearance of (*a*) the first living things; (*b*) sponges; (*c*) lung fish; (*d*) the first amphibians; (*e*) the first reptiles; (*f*) insects; (*g*) the dominance and disappearance of dinosaurs; (*h*) warm-blooded creatures (mammals and birds).

4. Important events in the development of plants have paralleled those of animal life. Some of these are:

a) Plants made their appearance about the same time that animals first appeared.

b) The first plants were similar to the simplest plants of today.

c) The first land plants appeared about the time of air-breathing animals.

d) The appearance of the first flowering plants was an important milestone in the development of plant life.

SELF-TESTING EXERCISES (P. 637). 1. Changes in the horse.

Change in Horse	*Change in Climate*
Horses' legs grew longer.	Grasslands instead of forests.
Teeth became harder and flatter.	Colder. Forests disappeared. Grassland appeared. Kind of food changed.
Necks became longer.	Needed to bend necks to ground to reach grass.

Change in Horse	*Change in Climate*
Heads lengthened. Eyes farther up. Bodies longer. More streamlined for running from enemies.	Grasslands instead of thick forests. Could not hide from enemies but had to run.
Feet changed. Toes disappeared.	Feet better adapted to hard ground and running.

2. Became extinct, that is, died out.

SELF-TESTING EXERCISES (P. 644). 1. (*a*) Rocks are made of substances that must have been formed from bodies of simple animals, for example, some kinds of limestone.

b) Soft-bodied, one-celled animals known as protozoans, much like present-day protozoa.

2. (*a*) Sponges, trilobites, early mollusks with shells, lung-fish.

b) Birds, mammals (mammoths, saber-tooth tiger, present-day birds and mammals, man).

3. (*a*) Appearance of vertebrates made possible development of land animals, since they could support themselves in air.

b) Air-breathing animals. Also made possible development of land animals, since they could breathe out of water.

c) Mammals. Could reproduce under conditions not favorable for reproduction by egg-laying reptiles and thus survived where many of the reptiles did not.

4. (*a*) Food plentiful; climate mild; at first were simple animals that could become suited to different habitats. Some lived in water, some on land, some in air. Some ate flesh, others plants.

b) Bodies became very complex and not adequate to environment. Huge armor plates, great teeth, and claws developed. Land rose and climate became cooler. Food scarce. Too big and heavy to catch smaller swifter animals for food. Eggs probably not incubated. Cooler climate hatched fewer eggs. Small mammals probably ate eggs. Fewer and fewer dinosaurs reproduced.

SELF-TESTING EXERCISES (P. 647). 1. Material for this table can be obtained from Table 6, page 626, of the text.

2. Answers will vary but should contain following ideas: (*a*) *Plant life*. (*1*) Probably bacteria and simple algae first. No remains of them.

2) Development of lime-forming algae. Limestone reefs made from their secretions.

3) Development of plants like present-day sea weeds.

4) Appearance of land plants. Rushes, ferns, etc., reproducing by spores.

5) Appearance of seed-bearing plants. In coal age, seed-bearing ferns and early cone-bearing trees.

6) Appearance of flowering plants in Cretaceous Period.

b) *Animal life.* (*1*) Simple animals. Rocks made of substance that probably formed bodies of these animals.

2) Single animals that formed fossils. Ancient sponges are this kind of animal.

3) Many sea-dwelling invertebrates. Mollusks with shells, and trilobites.

4) Appearance of first animals with backbones. Fish-like vertebrates with bony armor.

5) Appearance of first air-breathing animals. Sea-scorpions.

6) Appearance of lung-fish. Had air bladders similar to lungs of higher vertebrates.

7) Appearance of first reptiles and first insects.

8) Appearance of first warm-blooded animals, birds and mammals.

9) Mammals dominate earth and are of large size, such as mammoth, giant ground sloth.

10) Man has become dominant mammal.

3. Rocks known to be oldest contain fossils of plants that were very simple such as algae, or of ferns and fern-like plants that reproduced by means of spores. Remains of seed plants are found only in later rocks.

PROBLEM 3: WHY DO WE FIND DIFFERENT KINDS OF LIVING THINGS IN DIFFERENT PLACES? (P. 648)

The geographic distribution of animals (sometimes spoken of as the *isolation factor*) has aided in causing these living things to develop along lines that are different from the rest of their kind. This story is simply told in this problem by selecting interesting animals from many different geographic regions of the earth and showing how they have become isolated and the many body changes which have occurred as a result of this isolation.

An excellent way of presenting this material is to have the pupils make a very large map of the world on heavy paper. Show on this map the location of present land and water areas. Show also by means of a different color-legend land and water areas of a past geologic period (a generalized map of *Eocene Time* is good) in which prominent land bridges and other outstanding features appear. Reference to any good book on historical geology will provide such a map. See also Lucas, J. M., *The Earth Changes,* listed under *Readings in Science,* page 720, of the text.

As the study proceeds, have the pupils locate the present natural habitat of the animals under discussion by means of some suitable legend or device such as placing a small picture of each animal in its proper place on the map. The main ideas of Problem 3 are:

1. The appearance and disappearance of land bridges isolate certain kinds of animals. After their isolation, these animals undergo changes (during long spans of geologic time) and become different from animals of their kind which live elsewhere. Plants undergo similar changes when they become isolated.
2. Land may act as a barrier (*a*) in separating water animals, or (*b*) in separating land animals by means of mountain ranges.
3. Deserts may act as barriers that isolate animals.

SELF-TESTING EXERCISES (P. 652). 1. That each region has plants and animals that are found in that place and nowhere else.

2. Australia. Reasons that might be given: island; climate may have remained more constant since early times; joined to mainland at one time; early animals went there over land bridges; bridges disappeared and left primitive animals there; no animals from other regions could reach island.

SELF-TESTING EXERCISES (P. 656). 1. Animals brought in from other regions often thrive too well, for example, rabbit introduced into Australia, and starling and English sparrow into America.

2. Primitive animals believed to have migrated to Australia when it was part of mainland. Connections with mainland disappeared. Animals in Australia were isolated and no other animals could reach Australia.

3. (a) *Conditions vary in different parts of earth.* Plants and animals appear in places where are best suited to conditions.
b) *May be taken from one place to another by man.* May be able to thrive in places when taken there although they have not been able to reach place by themselves.
c) *Geographical features.* (1) Connections between parts of earth have changed during the years, making it possible or impossible for animals to go from one place to another place.
2) *Mountains.* Plants and animals become adapted to conditions on one side of mountain and do not migrate to other side.
3) *Deserts.* Conditions in desert make it impossible for animals from one side of desert to cross it to other side.

Legend under Figure 572 (p. 657). *Left:* Layers of sedimentary rock laid down; bending or folding occurred; erosion. *Right:* Lower layers of sedimentary rock laid down; bending occurred, erosion; top layers of rock laid down; unconformity between top and bottom layers.

Looking Back at Unit 11 (p. 657). 1. Refer to the unit graph on page 245. Pupil answers should include the major ideas listed at the beginning of each problem, pages 249, 253, and 256, arranged under the sub-problems as headings.

2. Comparison of classification with order of appearance:

Classification in Unit 2	*Order of Appearance on Earth*
One-celled animals	One-celled animals
Sponges	Sponges
Coelenterates	Trilobites and other invertebrates
Echinoderms	Fish
Segmented worms	Amphibians
Mollusks	Reptiles
Arthropods	Insects
Fish	Mammals
Amphibians	Birds
Reptiles	Man
Birds	
Mammals	

3. *Era:* longest division in earth's history.
Land bridges: land connection between two continents.

Radioactive element: one that changes until finally helium and lead are formed.

Primitive animal: early animal or simple one.

Geologic column: section down through rock layers that have been laid down on earth, with oldest layers at bottom and newest at top.

Carboniferous: coal-bearing; name given to period in which coal was formed.

Sea-scorpion: first air-breathing animal.

Oldest-known rock: piece of rock whose age has been determined from rate of change of radioactive elements in it.

Period: division of era.

Unconformities: places between layers of older rocks and layers of newer rock.

Dinosaur: one of reptiles, usually of large size, that once dominated earth.

Lung-fish: fish having air-bladders similar to lungs of higher vertebrates and possible ancestor of first land animals.

Platypus: primitive egg-laying mammal of Australia.

Geologic history: history of earth based on study of rocks, changes that have occurred in them, and plant and animal remains in them.

Metamorphic rock: sedimentary rock that has been changed by great pressure or heat to another form of rock.

ADDITIONAL EXERCISES (P. 658). 6. Short time of development of embryo in body of mother; young born in immature condition and develop further in pouch of mother.

PAMPHLET FOR UNIT 11

American Museum Natural History, New York, N. Y. Guide Leaflet Series. No. 75. *How Old Is the Earth?*

VISUAL MATERIALS FOR UNIT 11

MOTION PICTURES

Encyclopaedia Britannica Films
"A Lost World"

SPECIMENS

Ward's Natural Science Establishment, Rochester, N. Y.

UNIT 12

How Can Science Help Us Keep from Wasting Nature's Wealth?

FUNCTION AND SCOPE OF UNIT 12. The problem of conservation of natural resources becomes increasingly important each year. This fact is evident from the increasing amounts of money which are spent by governmental and other agencies each year, from the establishment of courses in college and universities for the training of workers for research in conservation problems, and from the various publications carrying articles for making a more or less apathetic public aware of the need of conserving our natural resources and of their part in this great undertaking.

Experience has taught that the best way to get an idea across to the general public is through the schools of the nation, slow though the process may be. Consequently, any good course in general science should point out some of the major problems to be solved in the broad field of conservation and should suggest ways of attacking these problems, even though the actual ways of solving some of them may not have been discovered.

Background material in the *Science Problems* series which adds meaning and significance to the study of this unit is:

Book 1

Unit 1. How scientists solve problems.

Unit 6. How we use and control fire.

Unit 11. How plants and animals live together (balance of life).

Book 2

Unit 3. How the earth's surface changes.

Unit 10. How life continues on the earth.

Unit 11. How we take care of the plants and animals we use.

Book 3

Unit 3. How plants and animals are fitted to the conditions around them.

Unit 9. How we harness the energy of nature.

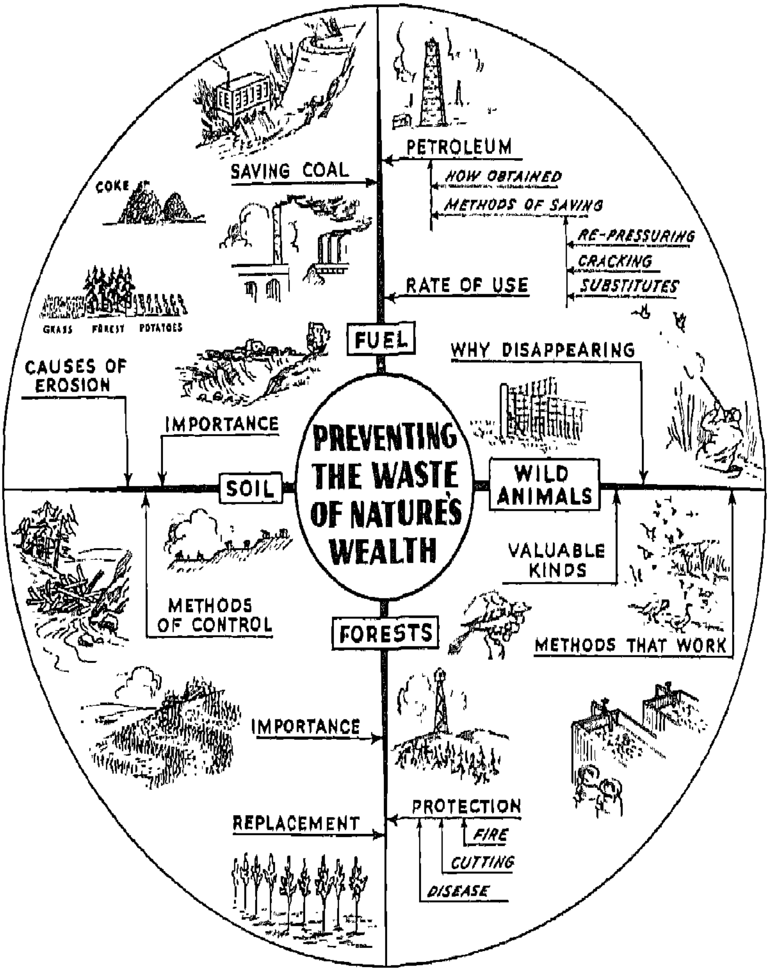


FIG. 18. GRAPH OF THE SUBJECT MATTER OF UNIT 12

This unit is an excellent one for concluding the series because of the general scientific background which has already been provided. However, it must not be assumed that experiencing this or any other unit on conservation can insure that the pupils will incorporate the principles of conservation into their thinking and practices. Conservation practices must be stressed at all possible points in the "in school" and "out of school" experiences of pupils until these practices become habits. The primary purpose, then, of this unit is to bring to the pupils' consciousness the need of conserving natural resources and to help them begin forming useful habits in regard to conservation practices.

INTRODUCTORY EXERCISES (P. 660). *1. Enough young plants and animals grow up in region to take place of those that die or are killed. Man may introduce new plants and animals and destroy plants and animals there; may cut trees, clear away underbrush and drain swamps, removing feeding and breeding places; may carry on destructive hunting practices.

*2. Animal whose kind no longer exists anywhere in world. Dodo and passenger pigeon are best known examples.

*3. Planting different crops in different years on same land. Helps keep soil fertile by replacing food materials used by certain crops. Destroys weeds and insect pests and fungi that cause certain plant diseases.

*4. By wind, water, and ice. Water most important. It can carry more soil than wind. Ice no longer important soil carrier.

*5. Top-soil is darker, looser upper soil. Sub-soil is deeper, lighter-colored soil. Plants grow better in top-soil because it contains humus (decayed plant and animal material) which provides necessary minerals. Also contains more air.

*6. Top-soil. Covers sub-soil and protects it. Lighter, looser soil more easily washed away.

*7. Erosion is wearing down and carrying away of rocks and soil by water, wind, or ice.

8. No. Conservation means that people must use natural resources with common sense and restraint so as to insure future supplies.

9. This exercise is needed to answer Problem to Solve 4, page 711. Sample responses are given in table on page 262.

CONSERVATION PROBLEMS OF MY COMMUNITY	WAYS OF TRYING TO SOLVE THESE PROBLEMS
1. Erosion is taking away some of the best soil from hillsides.	Making the rows run around the hill instead of up and down it.
2. Coal and oil supplies are being used up rapidly.	Using coke, regulating furnaces, using substitute fuels, etc.
3. Wild life is disappearing.	Protecting wild life by sanctuaries, feeding, restocking, etc.
4. Trees are being used up faster than they can be regrown.	Selective cutting of trees, fire protection, checking of tree diseases, replanting, etc.

LOOKING AHEAD TO UNIT 12 (P. 661). This introductory material may be used profitably in several ways in getting the pupils off to a good start in experiencing the unit. Some of these ways are: (1) Have pages 661-663 read before class and base the class discussions upon this material. (2) Have the material read in class and follow immediately with the discussion. (3) For several days previous to the use of these pages, have the pupils keep newspaper clippings relating to conservation problems and practices. Have the clippings read in class and check problems mentioned in the clippings with the problems raised on pages 661-663. Note that practically all conservation problems which arise will fall naturally into the four problem headings of the unit: *soil conservation*, *fuel conservation*, *conservation of animal life*, and *conservation of plant life*. (4) Select places in the community where conservation needs to be practiced—badly eroded areas, places where the need of reforestation is evident, places which could be used as game preserves, etc. Take the class on a preliminary survey trip to these places so that the problems of the unit may be based upon real needs which are evident in the local environment. Have the class take careful notes during the trip. At the first classroom lesson, have pages 661-663 read and relate this material to actual local conditions that were noted on the survey trip.

The aims of the entire unit are clearly expressed on page 663 and should be understood by each pupil from the use of the introductory material. These aims are: (1) to learn what some of the important problems of conservation are, (2) to learn some of the ways of solving these problems, and (3) to help put what has been learned into practice in the local community.

PROBLEM 1: HOW CAN WE SAVE OUR SOIL? (P. 664)

The first big task for the teacher in the presentation of this problem is to make pupils increasingly aware of the need of soil conservation, not passively aware of the need as is the case with most individuals but to the point where they want to do something about it. Only then can real learning begin and the pupils experience the problem as it should be experienced.

Cause-and-effect relationships must be stressed at all times. For example, be sure the factors affecting erosion (specifically enumerated on page 665) are thoroughly understood. Then the methods which have been effective in checking or preventing soil losses may be considered with emphasis upon selecting methods best suited to local conditions. Stress the last paragraph on page 672.

More and more educators are realizing that there must be closer coöperation between school and community agencies if education is to meet the demands placed upon it. Carrying out individual and school projects in checking erosion should enlist the aid of farm agents, 4-H clubs, and other people who are specially trained for this kind of work. The school should give full recognition and credit for out-of-school conservation work that is well done by the pupils. The major ideas to be stressed in the study of this problem are:

1. Soil erosion is fast becoming a serious problem in many parts of our country.

2. Important factors affecting soil erosion are (a) the amount and distribution of rainfall, (b) the contour of the land, (c) the kind of soil, and (d) the kind of farming practices.

3. Effective ways of controlling soil erosion are (a) contour

farming, (*b*) strip cropping, (*c*) terracing, and (*d*) the use of cover crops.

4. To be most effective, the method (or methods) of controlling soil erosion must be suited to the land upon which it is to be used.

SELF-TESTING EXERCISES (P. 668). 1. Most erosion occurs during seasons of heavy rain.

2. Large amount of rain distributed throughout the year will not cause nearly so much erosion as heavy rainfall in short periods. Illustrations will vary.

3. Contour means shape of surface of land. Steeper the slope, greater the erosion.

4. Clay and clay loam soils erode most easily. Sand and sandy loam erode least easily (sand will erode easily unless it contains organic matter). Clay and clay loam soils do not absorb water quickly but pack together and form hard surfaces. Rain runs off easily, carrying much soil. Sand and sandy loam, on the other hand, do absorb water quickly. Water sinks in instead of running off.

5. Answers will vary but should include idea that crops with fine roots (cover crops) check erosion while row crops increase erosion.

PROBLEMS TO SOLVE (P. 668). 1. Findings should agree with answer to Exercise 5 above.

2. Answers will vary. Erosion is a serious problem in most communities, although landowners are becoming increasingly aware of the problem.

SELF-TESTING EXERCISES (P. 675). 1. Paragraph should include:

a) Contour *farming*. Crop rows go across slopes instead of up and down. Rows form little dams that hold water. Water can thus soak into ground instead of running off, carrying soil.

b) *Strip cropping*. Crops are planted in strips of uniform width with rows running across slopes instead of up and down. Soil washed from cleanly cultivated strips is stopped by thick growth in strip below. Water can then sink into ground, depositing soil.

c) *Terracing*. Long, steep hillsides are built into short, gradual slopes something like steps. Shallow drainage ditches are usually built into each terrace. Water runs off gradual slope more slowly than off steep slope, thus checking erosion.

2. Answers should include the following ideas:
a) *Winter cover crops.* Roots hold soil together and stems protect it during season of heavy rain and snow.
b) *Permanent pasturage.* Roots, stems, and leaves help hold soil and prevent erosion.
c) *Planting grass in drainage ditches.* Grass holds back water so that it flows slowly. Roots also hold soil in place. Little erosion occurs.
d) *Planting or leaving wood lots.* Roots, stems, and leaves help hold soil and prevent erosion.

(Disadvantages include expense, effort, loss of land for crops, etc.)

3. (Teacher may refer pupils to *Science Problems, Book 1,* pages 15-21.) (a) *Solving problem scientifically:* (1) Recognize problem. (2) Find out what is already known about it. (3) Think of possible solutions. (4) Select best of these for trial. (5) Check plan. (6) Experiment. (7) Draw conclusion. (8) Apply it.
b) *Problem of erosion:* (1) Find out what is causing erosion. (2) Find out what others have done to solve same problem. (3) Think of ways of solving your problem. (4) Select best way or ways for trial on farm. (5) Check these by having soil expert go over them. (6) Try out selected plan or plans on small part of farm. (7) Decide whether to use plan on whole farm. (8) Use selected plan on whole farm.

PROBLEMS TO SOLVE (P. 675). 4. Yes. Composition may include idea that maintaining soil fertility enables plants to grow on soil so that it can be held in place by roots, stems, and leaves.

PROBLEM 2: HOW CAN WE SAVE FUEL FOR FUTURE USE? (P. 676)

The old saying that "you never miss the water until the well runs dry" is even more applicable to this problem than to the others of the unit. Change the word "water" to "oil," and the keynote of the problem is struck. The same thing applies to coal. One thing seems certain: since the supply of oil and coal is sufficient to meet all of our present needs, we are likely to continue the extravagant use of this seemingly inexhaustible supply. Also, satisfactory substitutes have not been developed by scientists as yet, even though they are working to find efficient uses for atomic energy and the radiant energy of the sun. So the best we can do is to teach the wise use of our natural fuel supplies in making them last as long as possible.

In so far as it is practicable, the material of this problem should be related to actual community conditions—examining the school furnace to learn how the maximum amount of heat can be obtained from the minimum amount of coal, examining different kinds of coal and coal products, collecting and studying petroleum and its by-products to learn how refining this resource increases its usefulness and provides valuable by-products.

Other types of related pupil activity which make real the conservation of fuel, are making and using in class explanations actual models of cross-sections of coal mines and oil wells (see Figure 587). Coal and oil companies are usually glad to coöperate in providing actual samples of their products, charts, posters, and other up-to-date printed material which are most valuable in the presentation of this problem. The major ideas are:

1. Coal, petroleum, and natural gas are natural resources which cannot be replaced.
2. The major conservation problem concerning fuel resources is to use fuels wisely to get the maximum good from the minimum amount and thus make the present supply last as long as possible.
3. Some effective ways of conserving the coal supply are (*a*) safer and more effective mining methods; (*b*) making coke from soft coal and using the coke for fuel, thus releasing valuable coal by-products; (*c*) proper regulation of furnaces; (*d*) using large central power plants instead of small, scattered plants; (*e*) using water power instead of coal as a source of energy whenever possible; and (*f*) using substitute fuels.
4. Our oil and natural gas supply can be conserved by using better methods of removing oil and natural gas from the ground, by developing better ways of refining oil, and by developing substitutes for oil fuels.

SELF-TESTING EXERCISES (P. 680). 1. Ways of saving coal should include (a) more thorough mining, (*b*) making coke from soft coal, (c) regulating amount of air in fires, (d) producing electricity from coal in large power plants, (e) using steam turbines instead of less efficient steam engines, (f) substituting water power for steam power, (g) using artificial fuels and waste wood.

Advantages will include saving coal for future use. Disadvantages include added cost, inconvenience, difficulty of getting people to follow methods, etc.

2. Coke is an excellent fuel that gives off great amount of heat when burned. When coal is made into coke, valuable by-products, such as gas, ammonia, and coal-tar, are obtained.

3. Wind, moving water (streams, waves, and tides), green plants (alcohol), sunlight.

Problems to Solve (p. 681). 1. Synthetic gasoline can be made from coal. Many drugs and chemicals can be prepared from coal-tar. New ones are being developed constantly.

3. Map should show coal fields in Appalachian Mountains from Pennsylvania south to Alabama, in Illinois and Indiana, and in Iowa south through Missouri, Kansas, Oklahoma, and Arkansas.

5. Two main methods of coal mining are pit mining and strip mining. In pit mining, shaft is sunk and tunnels dug off shaft into veins. In strip mining, soil and rock are removed and coal dug out with huge steam or electric shovels.

Self-Testing Exercises (p. 685). 1. Natural gas collected in domes of rock over oil and salt water collected below oil both exert pressure on oil. Pressure forces oil up through pipe when well is drilled into oil-bearing sand or rock.

2. Gasoline, kerosene, naphtha, fuel oil, paraffin, vaseline, lubricating oil may be mentioned.

3. Gas forced into well that seemingly has gone dry. Gas collects in rock dome over oil-bearing rock or sand. Increased pressure forces oil up through pipe again.

4. Re-pressuring old wells, increasing pressure in new wells by keeping gas in, cracking oil to get more gasoline, using substitute fuels such as alcohol, using smaller engines and thus less gasoline in automobiles. (Another way is polymerization of oil which consists in combining very light gas molecules into heavier gasoline molecules.)

Problems to Solve (p. 686). 1. Pipes, valves, and storage tanks are used. New methods are being developed all the time.

PROBLEM 3: HOW CAN WE BEST ENJOY OUR WILD ANIMALS? (P. 686)

Carefully controlled conservation practices have shown that rapidly disappearing wild life can be restored to its original abundance in a given region. The chief concern of conservationists with this problem is in securing coöperation of the public in the observance of scientifically sound practices in regard to hunting, fishing, and the preservation and restoration of feeding areas and the natural breeding grounds of wild life. Much stress should be placed upon deciding what *kinds* of animals should be saved. The sub-problem beginning on page 690 provides the basis for understanding the use of the scientific method in approaching this problem instead of depending upon hearsay and other false beliefs.

Pupils of this level have a well-developed sense of fair play. Consequently, a strong appeal for good sportsmanship in regard to hunting, fishing, and trapping practices is a vital instrument in the hands of the wise teacher. However, negative teaching is of little value at this point. For example, the "do not hunt" idea usually does more harm than good. The conservation idea is to hunt according to rules which are of proved value for the good of everyone concerned. Instead of the "do not hunt" idea, substitute positive values, such as the establishment of feeding stations and suitable nesting places.

Another caution which should be given is to guard against an over-sentimentalized presentation. This non-scientific procedure will quickly be sensed by the pupils (the boys particularly) and perhaps result in an attitude of contempt toward conservation. Securing the coöperation of local game wardens and other conservation agents lends authority to the experiences of this problem. The main ideas to be gained from the study of this part of the unit are:

1. Wild life is disappearing in many places because of (a) destruction of feeding and breeding places, (b) increase of natural enemies in many cases, and (c) modern methods of hunting, fishing, and trapping.

2. The problem of deciding what animals should be saved or destroyed should be left to scientific investigators, not to uninformed people.

3. Some of the effective ways of conserving wild life are (a) establishing sanctuaries, feeding grounds, and restoring natural habitats, (*b*) restocking game preserves, (c) providing commercial fur farms, (*d*) preventing forest fires from destroying natural habitats, (e) preventing animal diseases in so far as is possible, and (*f*) coöperating by obeying game laws and practicing good sportsmanship.

Self-Testing Exercises (p. 690). 1. (a) Breeding and feeding places (natural habitats) destroyed by clean farming, cutting down forests, draining swamps and ponds, etc. (*b*) Natural enemies increasing. (c) More effective methods of hunting, trapping, and fishing.

2. Answers may include stray animals, birds of prey, and man himself.

Self-Testing Exercise (p. 693). Explanation should include idea that careful study is needed to find which animals are harmful and should be killed and which ones are beneficial and should be protected. Only an expert investigator who has studied problem with great care is qualified to answer these questions. He will find out what the effect of protecting an animal will be and whether it will become a pest if its natural enemies are destroyed.

Problems to Solve (p. 693). 1 and 2. These problems provide an opportunity for fact-finding to check individual judgments. Answers may be compared to bring out points of similarity and difference.

Self-Testing Exercises (p. 699). 1. Text gives the following ways of protecting wild life: (a) bird-banding to find time and routes of migrations so as to protect birds during migration, (*b*) establishment of bird sanctuaries and game preserves, (c) feeding wild animals when food is hard to get, (*d*) providing breeding places and shelter by leaving trees and shrubs on land or planting them, (e) game laws with wardens to enforce laws against hunting, trapping, and fishing in certain places or at certain times, (*f*) re-stocking lakes and streams from fish hatcheries, (*g*) fur farms to cut down killing of fur-bearing animals, (*h*) prevention of forest fires that kill animals and destroy homes and food, (*i*) controlling animal diseases, (*j*) hunting and fishing licenses, and (*k*) good sportsmanship.

2. United States government together with state and local authorities is operating in many communities. Also, many communities have their own private organizations for protecting wild life.

PROBLEMS TO SOLVE (P. 699). 1 and 2. Here pupils have an opportunity to find out what governmental authorities are doing to protect wild life. City children frequently do not have any idea of the scope of wild-life conservation. Children in rural schools can profit by getting more detailed information.

PROBLEM 4: HOW CAN WE MAKE THE BEST USE OF OUR FORESTS? (P. 700)

As in the case of the other problems of this unit, the first procedure in attacking the problem of forest conservation is to make the pupils aware of the extent of the damage that has already been done and the resulting erosion and lumber scarcity. The material on pages 700-701 may be used as the basis for arousing interest. A brief, sincere talk by the teacher will be sufficient in most cases. The wise use of these pages should lead the pupils to write local, state, and national forestry agencies for reading material, posters, and charts which will prove most stimulating to the class. With the use of this material, related individual and group projects may be done along the lines suggested by the problem.

This part of the unit is purposely arranged to present the idea of first conserving the forests that still remain and then of repairing the damage that has already been done by unwise deforestation practices. Relationships between this problem and Problem 1, especially in regard to erosion, should be stressed.

In rural communities, visits to areas which have been reforested or which need reforesting will prove an excellent way of relating the material to local needs and existing conditions. In urban communities, visits to parks and other areas where tree planting has been done should help relate the classroom work to actual happenings. In either location, visits to nurseries, collection of specimens of diseased wood (burn diseased specimens when they have been studied), collection of samples of veneered wood, and tree-planting projects on the school grounds should be done by the pupils as the work of the problem proceeds.

Attention to particular problems of a region should be given in all cases. For example, in regions where the Dutch elm disease or the white-pine blister rust is a particular menace, much special work on the prevention of the spread of these diseases should be done. Secure the coöperation of local authorities in making the work as practical as is possible. The main ideas of the problem are:

1. Existing forests may be conserved by means of (a) modern fire prevention and protection methods, (b) selective cutting of trees, and (c) the study and practice of preventing tree diseases or of preventing the spread of these diseases.

2. Good reforestation practices include (a) analyzing soils to find what kinds of trees will grow best in them, (b) selecting proper sized seedlings for planting, (c) thorough preparation of the soil, (d) proper spacing in planting seedlings, and (e) proper care of seedlings during the process of transplanting.

Self-Testing Exercises (p. 706). 1. Text mentions the following: (a) forest wardens provided with special fire-fighting equipment, such as fire-rakes, chemical extinguishers, and water pumps; (b) "lookout towers" to discover and locate fires; (c) airplanes for same purpose; (d) cutting fire lanes to prevent spread of fires.

2. In selective cutting, only certain number of trees are cut at one time. Other trees are left to grow up, and new ones are planted to replace trees cut down. This keeps steady supply of trees growing for future use.

3. Yes. Tree diseases and insect pests destroy valuable trees that cannot easily be replaced.

Problems to Solve (p. 706). 2. Some of the agencies that may be mentioned are: U. S. (and state) Forest Service, American Forestry Association, National Wild Life Federation, Southern

Pulpwood Conservation Association, Izaak Walton League, West Coast Lumbermen's Association, Civilian Conservation Corps.

SELF-TESTING EXERCISE (P. 710). List should include (*a*) quality of soil (what kinds of trees will grow best in it), (*b*) size of seedlings to be planted, (*c*) preparation of land for planting, (*d*) spacing of planted seedlings, (*e*) care of seedlings during transplanting, (*f*) heeling-in seedlings, (*g*) depth of planting, (*h*) best time to plant seedlings.

PROBLEMS TO SOLVE (P. 711). 1-3. These problems give the pupils as individuals and as a group an opportunity to learn about their community at first hand. Solution of the problems will provide a thorough understanding of community activities and community needs in regard to conservation of trees.

LOOKING BACK AT UNIT 12 (P. 711). 1. Refer to the unit graph on page 260. Pupil answers should include the major ideas listed at the beginning of each problem, pages 263, 266, 268, and 271, arranged under the sub-problems as headings.

2. *Contour farming:* plowing so that furrows go across slopes instead of up and down. It helps prevent soil erosion.

Bituminous coal: soft coal; coke, gas, coal tar, ammonia, and many other products obtained from it.

Re-pressuring an oil well with gas is way of conserving oil by increasing yield of wells.

Clean farming: destroys natural habitat of wild animals by removing bushes, weeds, etc., which serve as breeding and feeding places.

Strip cropping: crops planted in strips running across slopes instead of up and down. Grass strips check water running off cultivated strips.

Cracking oil: increases yield of gasoline from petroleum by breaking up heavier oil molecules into lighter gasoline molecules.

Terracing: prevents erosion of soil by making steep slopes into series of step-like terraces.

Good sportsmanship: obeying game laws and not taking more game and fish than law allows.

Selective cutting: conserves trees by cutting down only certain number at one time and letting others grow so that supply will be available for future use.

Lignite: brown coal, intermediate stage between peat and soft coal.

Fuel oil: petroleum used for fuel by Diesel engines and furnaces.
Anthracite coal: hard coal, about 95% carbon.

ADDITIONAL EXERCISES (P. 711). 1-8. Material obtained from working out these exercises make interesting class displays. Reference materials can be worked up into reports. Bulletins from government agencies and information from private organizations should be available for pupil use.

BULLETINS AND PAMPHLETS FOR UNIT 12

Agriculture Circular
- No. 342. *Waterfowl Flyways of North America.* 5c

Agriculture Leaflet
- No. 208. *Intensive Projects under the Coöperative Farm Forestry Act.* 5c

Agriculture Misc. Publications
- No. 253. *Conservation Farming Practices and Flood Control.* 10c
- No. 291. *Teaching Conservation of Wildlife through 4-H Clubs.* 10c
- No. 321. *To Hold This Soil.* 45c
- No. 394. *Farms the Rains Can't Take.* 5c
- No. 446. *Publications and Visual Information on Soil Conservation.* 10c (Excellent source list of publications, charts, posters, filmstrips, slides, photographs, and motion pictures available from the Federal government. Has materials of regional as well as national scope.)

Farmers' Bulletins
- No. 1644. *Local Bird Refuges.* 5c
- No. 1719. *Improving the Farm Environment for Wildlife.* 5c
- No. 1758. *Cover Crops for Soil Conservation.* 5c
- No. 1776. *Strip Cropping for Soil Conservation.* 5c
- No. 1781. *Diseases of Upland Game Birds.* 5c
- No. 1789. *Terracing for Soil and Water Conservation.* 10c
- No. 1813. *Prevention and Control of Gullies.* 10c

Federal Security Agency
- Modern World at Work. No. 3. *Agriculture.* 15c

Soil Conservation Service
- *Use the Land and Save the Soil.* 5c

U. S. Forestry Service
Here Are Our Forests. 10c

U. S. Office of Education, Vocational Division, Bulletin No. 201. *Conserving Farm Lands: Planning for Soil-Erosion Control, Water Conservation, and Efficient Land Use.* 30c

Wildlife Circular
No. 3. *Federal Aid in Wildlife Restoration.* 5c

VISUAL MATERIALS FOR UNIT 12

CHARTS

Soil Conservation Service Charts (all 19 × 24 in.) 5c
No. 1. *Soil Erosion—Cause and Effect.*
No. 2. *Contour Farming for Soil and Water Conservation.*
No. 3. *Strip Cropping—an Erosion Control Practice.*
No. 4. *Terraces for Erosion Control.*
No. 5. *Cover Crops Protect Soil.*
No. 6. *Gully Control.*
No. 7. *Saving Soil and Water on Pasture Lands.*
No. 8. *Trees and Shrubs for Erosion Control.*
No. 9. *Wildlife—a Safe Use for Erodible Land.*
No. 10. *Farm Ponds.*

FILMSTRIPS

Society for Visual Education
"Forest Conservation"
"Our Forests and What They Mean to Us"
"Enemies of the Forest"
"Facts about Our Forests III" (Products and Conservation)

MOTION PICTURES

Encyclopaedia Britannica Films
"Anthracite Coal"
"Bituminous Coal"
"Producing Crude Oil"
"Conservation of Natural Resources"
"Refining Crude Oil"
"Reforestation of Waste Land"
"Planting and Care of Trees"
"Game Birds"
"Science and Agriculture"

PART THREE

Apparatus and Materials for Experimental Work

The following lists have been prepared to assist teachers in checking their equipment: (1) general lists of laboratory apparatus and materials, tools, and chemicals; (2) lists of laboratory apparatus and materials, chemicals, other apparatus and materials from local stores or home, and living materials needed especially for *Book 3*. They include only the standard apparatus that should be available in science classrooms for the best economy of pupil and teacher time. Much of it can be improvised, or inexpensive substitutes may be arranged where necessary.

Quantities listed provide only for having the experiments done as demonstrations or by one group of students at a time, or are practical minimum amounts for purchase. If a different plan is used, appropriate increases in the quantities should be made. Approximate costs, based on prices listed in catalogs of supply companies, are given in each list except for those items which may well be obtained free.

The general list includes items which are needed in any science room; practically every item would ordinarily be used in the study of each of the three books. A few of the articles listed are not actually called for in experiments but are almost indispensable. Many will be useful for pupils doing the "Problems to Solve."

There are also practical suggestions for ordering and caring for apparatus and materials and the addresses of some leading scientific supply companies.

1. GENERAL LISTS OF APPARATUS AND MATERIALS

LABORATORY APPARATUS AND MATERIALS

QUANTITY	ITEM	APPROXIMATE COST
1	aquarium, 6-gal.	$6.00
1	aquarium dip net	.20
1	balance, spring, graduated in ounces and grams	.65
6	beakers, Pyrex, 250 or 350 cc.	1.20
6	bottles, wide-mouth, 8 oz.	.43
1	burner, Bunsen (if gas is available; otherwise some satisfactory source of heat)	.50
12	candles, paraffin	.25
2	clamps, burette, single, adjustable	.60
2	clamps, right-angle	.50
1 bag	corks, assorted, some ordinary shapes, some flat	.55
1	cylinder, graduated, glass, 100 cc.	.85
4	dry cells	1.20
2	evaporating dishes, porcelain, 3 in. (75 mm.) dia. or larger	.36
1 box	filter paper (100 circles), 12 cm. dia.	.16
2	flasks, Pyrex, Erlenmeyer, 300 cc. or larger	.44
6	flower pots, medium size	.50
1	funnel, glass, 3 in. (75 mm.) dia.	.28
2	glass plates, 12 x 12 in. (to cover jars and pans)	.80
3	glass plates, 3 x 3 in.	.12
1 lb.	glass tubing, 3-4 mm. outside dia.	.60
1 lb.	glass tubing, 6 mm. outside dia.	.90
18 in.	glass tubing, 18 mm. outside dia.	.12
1	jar, glass, 1 qt.	.45
1	jar, glass, 2 qt.	.65
1	lamp chimney, ordinary	.25
1	lodestone	.25
2	magnets, bar (may well be rod-shaped cobalt-chrome)	.80
1	magnet, horseshoe, large (or U-magnet)	.18

QUANTITY	ITEM	APPROXIMATE COST
1	magnifier, tripod	$ 0.75
1	medicine dropper	.05
1	microscope, compound	65.80
½ oz.	microscope cover glasses	.33
½ gross	microscope slides, glass	.60
1 doz.	needles, steel knitting	.30
2	pans, round, flat, enamel, 2 qt. or larger	.60
1	pump, bicycle, hand pressure	.50
1	reading glass, or other large convex lens	1.00
2	ringstands, with small, medium, and large rings	2.10
6	rubber stoppers, No. 2, 1-hole	.12
6	rubber stoppers, No. 6, 1-hole	.30
6	rubber stoppers, 1-hole, to fit wide-mouth bottles	.36
6	rubber stoppers, 2-hole, to fit wide-mouth bottles	.36
6 ft.	rubber tubing, 5/16 in. inside dia. (for connecting burner)	.72
6 ft.	rubber tubing, 3/16 in. inside dia.	.48
10 lb.	sand, for aquarium	.50
2	stirring rods, glass, 8 in. x 3/16 in. dia.	.20
24	test-tubes, ordinary glass, 6 x ¾ in.	.60
2	test-tubes, Pyrex, 6 x ¾ in.	.10
1	test-tube brush	.10
3	test-tube holders	.30
1	test-tube rack	.40
2	thermometers, chemical 10-110° C. (double-scale graduated also on Fahrenheit)	2.40
1	trip scales, with 1 set brass weights—1-500 gm.	10.80
6	tumblers, glass	.60
¼ lb.	wire, iron, bare, No. 22 or 24	.13
1 spool	wire, iron, No. 30	.30
2 lb.	wire, copper, double cotton-covered, No. 18 or 22	1.80
2	wire gauze, iron, 6 x 6 in.	.20
		$112.69

Tools

QUANTITY	ITEM	APPROXIMATE COST
1 set	auger bits, 1 each, ¼, ½, 1 in.	$1.60
1	brace	1.50
1	file, round, small (4-in.)	.15
1	file, triangular, 4-in. or 6-in.	.12
1	forceps, steel or brass	.15
1	hammer, claw type	.25
1	knife, paring or large pocket-size	.35
2	needles, dissecting	.10
1	pliers, 6-in., wire cutting	.30
1	scalpel	.35
1	scissors, small, slender	.45
1	screwdriver, 4-in. blade	.25
1	shears, strong	1.00
1	trowel or spade	.30
		$6.87

Chemicals

QUANTITY	ITEM	APPROXIMATE COST
1 lb.	acid, hydrochloric, concentrated	$0.52
1 lb.	acid, nitric, concentrated	.54
1 lb.	acid, sulphuric, concentrated	.52
1 pt.	alcohol, denatured	.30
1 lb.	ammonium hydroxide, technical	.51
1 lb.	calcium oxide (for making limewater)	.30
1 lb.	copper (cupric) sulphate, technical	.30
1 cube	gum camphor	.30
4 oz.	iodine, Lugol's solution (to be diluted)	.40
1 lb.	potassium nitrate	.30
1 lb.	sodium bicarbonate (baking soda)	.20
1 lb.	sodium chloride (table salt)	.20
1 lb.	starch, laundry	.20
		$4.59

2. LISTS OF APPARATUS AND MATERIALS NEEDED ESPECIALLY FOR BOOK 3

LABORATORY APPARATUS AND MATERIALS

QUANTITY	ITEM	APPROXIMATE COST
1 lb.	ammonium chloride	$ 0.20
1	compass, magnetic	1.00
1	electrolysis apparatus	2.00
2	flower pots, one large, one small	.15
1	galvanometer	12.50
1	prism, glass, 60° angles	.60
1	pulley, single	.35
2	pulleys, double	.90
1	reading glass or other large convex lens	1.00
1	sending key, telegraph	2.00
1	sounder, telegraph	2.50
1	tripod (optional)	.35
3	tuning forks, two with same frequency, one with different frequency	3.75
1 spool	wire, copper, cotton-covered, No. 22 or 24	.50
1 spool	wire, copper, cotton-covered, No. 30	.75
		$28.55

MATERIALS TO BE OBTAINED WHEN NEEDED

(Because of the perishable nature of some of these items, they should be obtained a short time before they are needed. Page references to the text are given to indicate exactly when they will be required.)

QUANTITY	ITEM	QUANTITY	ITEM
1 culture	ameba for 10-25 pupils, $2.50, or prepared slide of ameba, 75c (p. 87)	several	seedlings, 4 or 5 in. high (bean, clover, morning glory, mustard, radish) (p. 61)
1 culture	paramecium for 10-25 pupils, $1.25, or prepared slide of paramecium, 50c (p. 88)	several	seeds, bean or pea (p. 62)
		several	seeds, radish (p. 63)
		1	sensitive plant (p. 65)
			soil, rich (pp. 61, 62)

APPARATUS AND MATERIALS FROM LOCAL STORES OR HOME

QUANTITY	ITEM
1 strip	aluminum, 1 x 5 in.
1	bell or buzzer, electric
1	board, 26 in. long, ½ in. thick
1	board, 5 ft. long, 1 ft. wide
1	box, 2 ft. square
1	box, cardboard, shallow (to hold compass)
1	box, chalk or cigar
2	boxes, cigar, with covers
1	box, large, with hole, 2 in. dia., in one side
1	box, opaque, or reflector
1 strip	brass, 1 x 5 in.
1	brush, small scrub
1	bugle, cornet, or trombone
1	card, small
6 pieces	cardboard, large
1	clip, paper
1 yd.	cloth, black
¼ yd.	cloth, silk
¼ yd.	cloth, woolen
1	coin, silver
1	comb, hard rubber
2 strips	copper, 1 x 5 in.
10 ft.	cord, strong
1	cylinder, cork, balsa, or white pine, 1 in. dia., 2 in. long
1	disk, galvanized iron, 3 in. dia.
2	disks, galvanized iron, 12 in. dia.
1	drum
1	dry cell, worn-out, or flashlight battery
1	flashlight
1	flashlight bulb and socket
1 piece	glass, window, 3x6 in.
1 piece	glass, window, 6 in. square
1 bottle	glue
1	harmonica
1	hook (to hold spring)
1	iron (or steel) rod, 3 ft. long
1	iron rod, soft, 12 in. long, or 2 U-shaped pieces of iron
1 strip	iron or tin-plate, 1 x 5 in.
1	lamp with opaque shade
2 strips	lead, 1 x 5 in.
1	mandolin, guitar, or violin
1 box	matches, safety
1	mirror, flat, metal or glass
few	nails, large
few	nails, small
1	needle, sewing-machine
1 can	oil, machine
	paper, white
1 doz.	pencils, round
1	phonograph

QUANTITY	ITEM
1	phonograph record
1	piano
1 pkg.	pins, common
1	protractor
1	push-button or switch, single pole, single throw
2	roller-skate wheels
1 box	rubber bands, assorted
1	ruler or yardstick
15 lb.	sand
1 bar	soap
1	spring from window-shade roller
1	steel rod, 12 in. long, ¼ in. dia.
1 ball	string
1	string, guitar or piano, coarse
¼ lb.	sugar, cane or beet
1 spool	thread, silk or cotton
1	tin can (for turbine blades)
1	tin can, friction-top, 3 in. dia.
3	tumblers or drinking glasses (or ½-pt. jars)
½ pt.	vinegar
1	wagon or cart, toy
1 qt.	water, distilled
	wax, sealing
1 piece	white pine or balsa (for propeller)
1 piece	wood, 6 in. square, 1 in. thick
2	wood circles, one 2 in. dia., one 10 in. dia.
	wood (pine) splinters
2	yardsticks
1 strip	zinc, 1 x 5 in.

3. SUGGESTIONS FOR ORDERING AND CARING FOR APPARATUS AND MATERIALS

In equipping the laboratory much depends on local conditions and available funds. No teacher of introductory science should feel it necessary to have a large appropriation for apparatus and materials. He will find available in other science laboratories many materials that he can borrow, and his students will gladly help him bring to the laboratory from home and neighborhood stores a considerable portion of the necessary supplies. It is only essential to plan far enough in advance for the experimental work and then proceed to use to the best advantage such supplies as are available through purchase, through loan by other science teachers, and through the teacher's ingenuity and pupils' assistance.

If the apparatus and materials are properly cared for, and if pupils take pride in helping to provide essential materials, the store of equipment may be built up within a few years. Some materials must be purchased, of course, but there are ways to raise the necessary funds even if the school appropriation is smaller than the amount needed.

ORDERING APPARATUS AND MATERIALS

In ordering supplies it is first necessary to survey the course to be taught and then to select that material which appears to be most fundamental to the proper study of the course. The lists that are given represent these fundamental materials for *Science Problems, Book 3*.

The next step is to submit copies of your list of necessary materials to three or four of the leading laboratory supply companies for an estimate. This step applies, of course, to those articles that cannot be obtained from home or from neighborhood stores. A list of companies is given on page 284. Catalogs (that may be had on request) from two or three of the nearest supply houses may profitably be consulted in making your list.

When the estimates are received, the next step is to place the order in whole or in part with the company (or companies) that furnishes the best estimate on the entire order or on any items of the order. Having the catalogs of the companies at hand, it will be easy to look up the specifications of any item that they quote.

In places where the teacher does not find it possible or practicable to proceed as suggested, the list may be sent to the purchasing agent or principal, who will forward it to the supply companies.

If a card index is kept for all equipment, it will be an easy matter to know at any time what equipment and supplies are on hand and also to make out the order for the next year. Some teachers prefer to keep a notebook list of supplies on hand.

Such a list is not as flexible or as handy as an alphabetical card index.

Bar magnets		C.A. Co. Cat. No. 48			Case 8 Shelf C
Date	On Hand	Ordered	No.	Price	Remarks
10/1/41	2	2/1/39	2	.80	Loaned to Mr. Thomas 1/15/40 Returned 2/12/40

FIG. 19. FORM FOR LABORATORY INDEX CARD

The authors have found that a card index of apparatus and materials is a great convenience in ordering and in making the annual inventory. Furthermore, such a card index is a permanent part of the laboratory, and a new teacher may quickly familiarize himself with the apparatus on hand and its location. The form of card found most useful is shown in Figure 19. Pupils will gladly help in ruling the cards; they may be prepared from a stencil, or the school printing class may make them. The 4 x 6 size has been found to be most satisfactory.

Such a card may contain an exact description of the article with a reference to catalog number or letter of a laboratory supply company, as well as the price, as indicated on the form shown above. With the item once entered on the card, it is not necessary to turn to the catalog every time a new order is to be placed. It is only necessary to leaf through the cards as the inventory is made, enter the number or quantity on hand, and, if an additional supply is needed, make proper entry in the columns for that purpose. Any secretary or pupil can then take the cards and make up a list of items to be ordered. If prices are entered on the cards, queries from the principal or superintendent concerning the value of apparatus and materials on hand may be quickly and accurately answered.

CARING FOR APPARATUS AND MATERIALS

If enough cabinet space is available, the authors have found the following plans and practices of value:

a) Store all "chemicals" and other materials in alphabetical order.

b) Store assembled apparatus used with particular units in groups by units.

c) Have such commonly used apparatus as test-tubes, Bunsen burners, and matches near or on the demonstration table.

d) If apparatus is out of order, do not put it away until it is repaired.

e) Have pupils acquainted with the plan of storing apparatus so that they will not waste time in getting it and so that it will always be returned to the proper place.

f) Number the sections of cabinets and cases in order.

4. SCIENTIFIC SUPPLY COMPANIES

Biological Supply Co., 1176 Mt. Hope Ave., Rochester 7, N. Y.

California Biological Service, 1612 W. Glenoaks Blvd., Glendale, Calif. (Soilless plant culture)

Cambosco Scientific Co., 37 Antwerp St., Brighton Station, Boston 35, Mass.

Carolina Biological Supply Co., Elon College, N. C.

Central Scientific Co., 1700 Irving Park Blvd. (Lakeview Station), Chicago 13, Ill.; 441 Clinton Avenue, Newark 8, N. J.; 79 Amherst St., Cambridge 42, Boston, Mass.

Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago 22, Ill.

Clay-Adams Co., 44 East 23rd St., New York 10, N. Y. (Models and charts)

Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago 40, Ill. (Models and charts)

Empire Laboratory Supply Co., 507-559 W. 132d St., New York, N. Y.

General Biological Supply House, 761-763 E. 69th Place, Chicago 37, Ill.

Heil Corp., 210 S. Fourth St., St. Louis 2, Mo.

Marine Biological Laboratory, Woods Hole, Mass.

Michigan Biological Supply House, 206 S. First St., Ann Arbor, Mich.

Millard Heath Co., 325 Olive St., St. Louis 2, Mo.

New York Scientific Supply Co., 28 West 30th St., New York 1, N. Y.

A. J. Nystrom and Co., 3333 Elston Ave., Chicago 18, Ill. (Charts)

Oregon Biological Supply Co., 303 N. E. Multnomah, Portland 12, Ore.

Scientific Supplies Co., 122 Jackson Ave., Seattle 4, Wash.

Standard Scientific Supply Corp., 34-38 West 4th St., New York 12, N. Y.

Wards Natural Science Establishment, 3000 Ridge Road, East, Rochester 9, N. Y.

W. M. Welch Scientific Co., 1515 N. Sedgwick St., Chicago 10, Ill.

Western Laboratories, 826 Q St., Lincoln, Nebr.

PART FOUR

Publications and Teaching Materials for the Science Teacher

1. READING AND REFERENCES

GENERAL READING ON THE TEACHING OF SCIENCE

Croxton, W. C. *Science in the Elementary School.* New York: McGraw-Hill, 1937.

Curtis, F. D. *A Digest of Investigations in the Teaching of Science.* Philadelphia: Blakiston, 1925.

Curtis, F. D. *A Second Digest of Investigations in the Teaching* of Science. Philadelphia: Blakiston, 1931.

Curtis, F. D. *A Third Digest of Investigations in the Teaching of* Science. Philadelphia: Blakiston, 1939.

Downing, E. R. *An Introduction to the Teaching of Science.* Chicago: University of Chicago Press, 1934.

Heiss, E. D., Obourn, E. S., and Hoffman, C. W. *Modern Methods and Materials for Teaching Science.* New York: Macmillan, 1940.

Hunter, George W. *Science Teaching at Junior and Senior High School Levels.* New York: American Book, 1934.

Mayfield, John C., Parker, Bertha M., Blough, Glenn O. *Science Instruction in Elementary and High School Grades.* Chicago: University of Chicago Laboratory Schools, 1939.

Miller, David F., and Blaydes, Glenn W. *Methods and Materials for Teaching Biological Sciences.* New York: McGraw-Hill, 1938.

National Society for the Study of Education, Thirty-first Yearbook, Part I. *A Program for Teaching Science.* Forty-sixth Yearbook, Part I. *Science Education in American Schools.* Chicago: University of Chicago Press, 1932 and 1947.

Noll, Victor H. *The Teaching of Science in Elementary and Secondary Schools.* New York: Longmans, 1939.

Palmer, E. Laurence. *Nature Magazine's Guide to Science Teaching.* Washington, D. C.: American Nature Association, 1936.

Preston, Carleton E. *The High School Science Teacher and His Work.* New York: McGraw-Hill, 1936.

Progressive Education Association. *Science in General Education.* New York: Appleton-Century, 1938.

Science Instruction and America's Problems. Washington, D. C.: Department of Science Instruction of the N. E. A., 1940.

Skinner, Charles E. (ed.) *Educational Psychology.* New York: Prentice-Hall, 1936.

Slavson, S. R., and Speer, R. K. *Science in the New Education.* New York: Prentice-Hall, 1934.

Underhill, O. E. *The Origins and Development of Elementary-School Science.* Chicago: Scott, 1941.

READING ON VARIOUS ASPECTS OF SCIENCE TEACHING

The American Institute of the City of New York, 310 Fifth Ave., New York, N. Y., is organized to direct and utilize the imaginative faculties of youth. It has 730 juvenile clubs under its wings. Write to it for information about science clubs.

Atyeo, Henry C. *The Excursion as a Teaching Technique.* New York: Bureau of Publications, Teachers College, Columbia University, 1939.

Cook, Dorothy E., and Rahbek-Smith, Eva, *Educational Film Catalog.* New York: Wilson, H. W., 1939.

Exelby, C. L., and Gambill, L. B. *Science Club Manual.* Lansing, Mich.: The National Club Manual Co., 1931.

Harrison, Margaret. *Radio in the Classroom.* New York: Prentice-Hall, 1937.

Hoban, Charles F., Hoban, Charles F., Jr., and Zisman, Samuel B. *Visualizing the Curriculum.* New York: Cordon, 1937.

Hurley, Richard James. *Key to the Out-of-Doors.* New York: Wilson, H. W., 1938. (Lists books, films, slides, etc.)

Laine, Elizabeth. *Motion Pictures and Radio: Modern Technique for Education.* New York: McGraw-Hill, 1938.

Moore, E. M., *Youth in Museums.* Philadelphia: University of Pennsylvania Press, 1941.

Ramsey, Grace F. *Educational Work in Museums of the United States.* New York: Wilson, H. W., 1938.

Ruch, G. M. *The Objective or New-Type Examination.* Chicago: Scott, 1929.

Towne, Mary E. *Teaching with Motion Pictures: A Guide to Sources of Information and Materials.* Teachers College Library Contributions, No. 1. New York: Teachers College, Columbia University, 1940.

Turtox Service Leaflets, Turtox Teacher's Manual. Chicago: General Biological Supply House. Free.

Vinal, W. G. *Nature Recreation:* group guidance for the out-of-doors. New York: McGraw-Hill, 1940.

Wood, B., and Freeman, F. N. *Motion Pictures in the Classroom.* Boston: Houghton, 1929.

Woodring, M. N., Oakes, M. E., and Brown, H. E. *Enriched Teaching of Science in the High School.* New York: Bureau of Publications, Teachers College, Columbia University, Revised Ed. 1941. (Lists available free materials.)

REFERENCE BOOKS

Many of these books are surveys of important departments of science or of the whole science field. Non-technical in style, they are designed to broaden the reader's background of information and increase his insight into the significance of science.

Allee, Warder C. *The Social Life of Animals.* New York: Norton, 1938.

Bartky, Walter. *Highlights of Astronomy.* Chicago: University of Chicago Press, 1936.

Bond, Phyllis. *Watching Wild Life.* New York: Longmans, 1937.

Borsook, Henry. *Vitamins: What They Are and How They Can Benefit You.* New York: Viking, 1940.

Buchsbaum, Ralph. *Animals without Backbones.* Chicago: University of Chicago Press, 1948.

Carlson, Anton J., and Johnson, Victor. *The Machinery of the Body.* Chicago: University of Chicago Press, 1941.

Chamberlain, Charles J. *Elements of Plant Science.* New York: McGraw-Hill, 1930.

Clendenning, Logan. *The Human Body.* (Rev. Ed.) New York: Knopf, 1945.

Collingwood, G. H. *Knowing Your Trees.* Washington, D. C.: American Forestry Association, 1947.

Coulter, Merle C. *The Story of the Plant Kingdom.* Chicago: University of Chicago Press, 1936.

Cressy, Edward. *Discoveries and Inventions of the Twentieth Century.* New York: Dutton, 1930.

Croneis, Carey, and Krumbein, William C. *Down to Earth.* Chicago: University of Chicago Press, 1936.

Curie, Eve. *Madame Curie: A Biography.* New York: Doubleday, 1937.

Fairchild, David G. *The World Was My Garden.* New York: Scribner, 1938.

Findlay, Alexander. *A Hundred Years of Chemistry.* New York: Macmillan, 1937.

Furnas, C. C. *The Next Hundred Years.* New York: Blue Ribbon, 1938.

Harvey, William. *Simple Lessons in Human Anatomy.* Chicago: American Medical Association, 1931.

Hylander, C. J. *Plants and Man.* Philadelphia: Blakiston, 1941.

Jacobs, Morris J. *The Chemical Analysis of Foods and Food Products.* New York: Van Nostrand, 1938.

The Layman Scientist in Philadelphia. Edited by W. Stephen Thomas. Committee on Education and Participation in Science. Philadelphia, Pa.: American Philosophical Society, 1940.

Lemon, Harvey B. *From Galileo to the Nuclear Age.* Chicago: University of Chicago Press, 1946.

Lynde, C. J. *Science Experiments with Home Equipment.* Scranton, Pa.: Int. Textbook, 1937.

Lynde, C. J. *Science Experiments with Inexpensive Equipment.* Scranton, Pa.: Int. Textbook, 1939.

Matlin, D. R. *Growing Plants Without Soil.* New York: Chemical Pub., 1940.

Orientation in Science. By eleven members of the University of Rochester faculty. Edited by C. W. Watkeys. New York: McGraw-Hill, 1938.

Outline of Science, The. Edited by J. Arthur Thomson. New York: Putnam, 1937.

Pfeiffer, John. *Science in Your Life.* New York: Macmillan, 1939.

Richards, Harold. *The Universe Surveyed.* New York: Van Nostrand, 1937.

Robbins, William J., and Rickett, Harold W. *Botany.* New York: Van Nostrand, 1939.

Snell, Foster Dee and Cornelia T. *Chemicals of Commerce.* New York: Van Nostrand, 1939.

Vallery-Radot, René. *Life of Pasteur.* New York: Garden City Pub. Co., 1940.

Wells, H. G., and Huxley, Julian S. *The Science of Life.* New York: Doubleday, 1934.

World and Man As Science Sees Them. By twelve members of University of Chicago faculty. Edited by Forest Ray Moulton. Chicago: University of Chicago Press, 1937.

PUBLISHERS' NAMES AND ADDRESSES

This list includes the names and addresses of the publishers of the books listed in *Readings in Science* in the text as well as of those given in the *Guidebook.* The publishing companies are listed alphabetically according to the abbreviations commonly used for them.

American Book: American Book Company, 88 Lexington Ave., New York, N. Y.
American Forestry Association, 919 Seventeenth St., N. W., Washington, D. C.
Amer. Med. Assoc.: American Medical Association, 535 N. Dearborn St., Chicago, Ill.
American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.
American Philosophical Society, Independence Square, Philadelphia, Pa.
American Viewpoint Society, Inc., 13 Astor Place, New York, N. Y.
Appleton-Century: Appleton-Century Crofts, 35 W. 32nd St., New York, N. Y.
Beacon Press: The Beacon Press, Inc., 25 Beacon St., Boston, Mass.
Bell and Sons: George Bell and Sons, Ltd., York House, 6 Portugal St., Lincoln's Inn Fields, London, WC2.
Blakiston: P. Blakiston's Sons and Co. (Now the Blakiston Company), 1012 Walnut St., Philadelphia, Pa.
Blue Ribbon: Blue Ribbon Books, 14 W. 49th St., New York, N. Y.
Bobbs: Bobbs-Merrill Company, 724 N. Meridian St., Indianapolis, Ind.
Boy Scouts of America, 2 Park Ave., New York, N. Y.
Butterworth, T.: Thornton Butterworth, Ltd., 15 Bedford St., Strand, London, WC2.
Chemical Pub.: Chemical Publishing Co., Inc., 26 Court St., Brooklyn, N. Y.
Christopher: Christopher Publishing House, 1140 Columbus Ave., Boston, Mass.
Columbia Univ. Press: Columbia University Press, 2960 Broadway, New York, N. Y.
Compton: F. E. Compton and Co., 1000 N. Dearborn St., Chicago, Ill.
Comstock: Comstock Publishing Co., Inc., 124 Roberts Place, Cornell Heights, Ithaca, N. Y.
Cordon: The Cordon Co., Inc., New York, N. Y. (Its publications have been acquired by The Dryden Press, 386 Fourth Ave., New York, N. Y.)
Coward-McCann: Coward-McCann, Inc., 2 W. 45th St., New York, N. Y.
Crowell: The Thomas Y. Crowell Company, 432 Fourth Ave., New York, N. Y.
Day: John Day Co., Inc., 2 W. 45th St., New York, N. Y.

Dial Press: Dial Press, Inc., 432-438 Fourth Ave., New York, N. Y.

Dodd: Dodd, Mead and Company, Inc., 432 Fourth Ave., New York, N. Y.

Donahue: M. A. Donahue and Co., 711 S. Dearborn St., Chicago, Ill.

Doubleday: Doubleday, Doran and Co., Inc., 14 W. 49th St., New York, N. Y.

Duffield: Duffield, Green, Inc. (Acquired by Dodd, Mead and Co.)

Dutton: E. P. Dutton and Co., Inc., 300 Fourth Ave., New York, N. Y.

Flanagan: A. Flanagan Company, 920 N. Franklin St., Chicago, Ill.

Follett: Follett Publishing Co., 1255 S. Wabash Ave., Chicago, Ill.

Funk: Funk and Wagnalls Company, 153 East 24th St., New York, N. Y.

Garden City Publishing Co., Inc., 14 W. 49th St., New York, N. Y.

Gardner: Wells, Gardner, Darton and Co., Ltd., 65-71 Brighton Road, Redhill, Surrey.

Ginn: Ginn and Co., Statler Building, Boston, Mass.

Girl Scouts of America: Girl Scouts, Inc.,155 East 44th St., New York, N. Y.

Greenberg: Greenberg, Publisher, Inc., 201 East 57th St., New York, N. Y.

Grolier Soc.: Grolier Society, 2 W. 45th St., New York, N. Y.

Halcyon: (See Blue Ribbon Books.)

Hale: Ralph T. Hale and Company, 6 Beacon St., Boston, Mass.

Hale, E. M.: E. M. Hale and Company Publishers, 320 S. Barstow St., Eau Claire, Wis.

Harcourt: Harcourt, Brace and Company, Inc., 383 Madison Ave., New York, N. Y.

Harper: Harper and Brothers, 49 E. 33rd St., New York, N. Y.

Harter: Harter Publishing Company. (Acquired by Beckley-Cardy Co., 1632 Indiana Ave., Chicago, Ill.)

Heath: D. C. Heath and Company, 285 Columbus Ave., Boston, Mass.

Holt: Henry Holt and Company, Inc., 257 Fourth Ave., New York, N. Y.

Houghton: Houghton Mifflin and Co., 2 Park St., Boston, Mass.

Int. Textbook: International Textbook Company, 1001 Wyoming Ave., Scranton, Pa.

Knopf: Alfred A. Knopf, Inc., 501 Madison Ave., New York, N. Y.

Leisure League: Leisure League of America, Inc., 1309 W. Main St., Richmond, Va.

Lippincott: J. B. Lippincott Company, East Washington Square, Philadelphia, Pa.

Little: Little, Brown and Company, 34 Beacon St., Boston, Mass. (School books acquired by D. C. Heath)

Longmans: Longmans, Green and Co., 55 Fifth Ave., New York, N. Y.

Lothrop: Lothrop, Lee, and Shepard Co., 419 Fourth Ave., New York, N. Y.

Macmillan: The Macmillan Co., 60 Fifth Ave., New York, N. Y.

McGraw-Hill: McGraw-Hill Book Company, Inc., 330 W. 42d St., New York, N. Y.

Macrae-Smith: Macrae-Smith Co., 225 South 15th St., Philadelphia, Pa.

Messner: Julian Messner, Inc., Publishers, 8 W. 40th St., New York, N. Y.

Modern Age: Modern Age Books, Inc., 432 Fourth Ave., New York, N. Y.

Morrow: William Morrow and Co., Inc., 425 Fourth Ave., New York, N. Y.

N. E. A.: National Education Association of the United States, 1201 Sixteenth St., N.W., Washington, D. C.

Nelson, C. C.: C. C. Nelson Publishing Company, 213-215 E. Washington St., Appleton, Wis.

Newman, Hugh F.: Hugh F. Newman and Company, 420 E. Seventh St., Los Angeles, Calif.

Norton: W. W. Norton and Co., Inc., 101 Fifth Ave., New York, N. Y.

Owen: F. A. Owen Publishing Company, Dansville, N. Y.

Oxford: Oxford University Press, 114 Fifth Ave., New York, N. Y.

Page: L. C. Page and Company, 53 Beacon St., Boston, Mass.

Prentice-Hall: Prentice-Hall, Inc., 70 Fifth Ave., New York, N. Y.

Public School: Public School Publishing Co., 509-513 N. East St., Bloomington, Ill.

Putnam: G. P. Putnam's Sons, 2-6 W. 45th St., New York, N. Y.

Quarrie: W. F. Quarrie and Co. (now The Quarrie Corporation) 35 E. Wacker Drive, Chicago, Ill.

Rand: Rand McNally and Company, 536 S. Clark St., Chicago, Ill.

Reinhold: Reinhold Publishing Corporation, 330 W. 42nd St., New York, N. Y.

Reynal: Reynal and Hitchcock, Inc., 8 West 40th St., New York, N. Y.

Scott: Scott, Foresman and Company, 433 East Erie St., Chicago 11, Ill.

Scribner: Charles Scribner's Sons, 597-599 Fifth Ave., New York, N. Y.

Silver: Silver, Burdett and Company, 45 E. Seventeenth St., New York, N. Y.

Stokes: Frederick A. Stokes Company. (Acquired by J. B. Lippincott Company)

Univ. of Chicago Press: University of Chicago Press, 5750 Ellis Ave., Chicago, Ill.

Univ. of Okla. Press: University of Oklahoma Press, Faculty Exchange, Norman, Okla.

Univ. of Pa. Press: University of Pennsylvania Press, 3436 Walnut St., Philadelphia, Pa.

University Society Inc., 468 Fourth Ave., New York, N. Y.

Vanguard: Vanguard Press, Inc., 424 Madison Ave., New York, N. Y.

Van Nostrand: D. Van Nostrand Company, Inc., 250 Fourth Ave., New York, N. Y.

Viking: Viking Press, 18 E. 48th St., New York, N. Y.

Wiley: John Wiley and Sons, Inc., 440 Fourth Ave., New York, N. Y.

Williams and Wilkins: The Williams and Wilkins Company, Mt. Royal and Guilford Aves., Baltimore, Md.

Wilson, H. W.: H. W. Wilson Co., 950 University Ave., New York, N. Y.

Winston: John C. Winston Company, 1006-1026 Arch St., Philadelphia, Pa.

World Book: World Book Company, 313 Park Hill Ave., Yonkers-on-Hudson, N. Y.

2. PERIODICALS FOR TEACHERS AND PUPILS

(Starred [*] publications are suitable for pupils.)

The American Biology Teacher, published by The National Association of Biology Teachers, N. Queen St. and McGovern Ave., Lancaster, Pa. (Monthly from October to May. Annual membership in The National Association of Biology Teachers, including subscription, $2.00.)

**American Forests*, published by The American Forestry Association, 919 Seventeenth St., Washington, D. C. (Monthly. $5.00 a year; 50c a copy.)

**Audubon Magazine*, formerly *Bird Lore*, published by The National Audubon Society, 1000 Fifth Ave., New York 28, N. Y. (A bimonthly magazine devoted to the study and protection of birds and mammals. $2.50 a year; 45c a copy.)

**Building America*, published for The Society for Curriculum Study, 140 N. 6th St., Philadelphia, Pa. Distributed by the Americana Corporation, 2 W. 45th St., New York, N. Y. (Monthly from October through May. $3.00 for single set of 8 units; 45c a single copy.)

Consumers' Guide, published by the Department of Agriculture, Washington, D. C. (Monthly from June through September; semi-monthly from October through May. 50c a year; 5c a copy.)

**Current Science*, published by American Education Press, Inc., 400 Front St., Columbus, Ohio. (Weekly during school; $1.20 a year.)

**Frontiers, A Magazine of Natural History*, published by The Academy of Natural Sciences of Philadelphia, 19th St. and The Parkway, Philadelphia, Pa. (Five times a year—October, December, February, April, June. $1.50 a year.)

Hygeia, The Health Magazine, published by The American Medical Association, 535 N. Dearborn St., Chicago, Ill. (Monthly. $2.50 a year; 25c a copy.)

Journal of Chemical Education, official publication of The Division of Chemical Education of the American Chemical Society, 20th and Northampton Sts., Easton, Pa. (Monthly. $3.00 a year; 50c a copy.)

**The Junior Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Monthly. $1.50 a year.)

**The National Geographic Magazine*, published by The National Geographic Society, 16th and M Sts., N. W., Washington, D. C. (Monthly. Annual membership in The National Geographic Society, including subscription, $5.00.)

**Natural History Magazine*, published by The American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Monthly except July and August. $5.00 a year; 50c a copy.)

**Nature Magazine*, published by the American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C. (Monthly. $4.00 a year; 50c a copy.)

Peabody Journal of Education, published by George Peabody College for Teachers, Nashville, Tenn. The July issue of each year contains Mr. H. A. Webb's "High School Science Library" for the preceding twelve months which may be obtained as a reprint from the author. (Monthly. $2.00 a year; 40c a copy.)

*Popular Mechanics, 200 E. Ontario St., Chicago, Ill. (Monthly. $2.50 a year, $4.00 for two years; 25c a copy.)

*Popular Science Monthly, published by Popular Science Publishing Co., Inc., 353 Fourth Ave., New York, N. Y. (Monthly. $2.50 a year; 25c a copy.)

School Science and Mathematics, publication of the Central Association of Science and Mathematics Teachers, Inc. Published at 450 Ahnaip St., Menasha, Wis. (Monthly except July, August, and September. $3.50 a year; 40c a copy.)

*Science Digest, published by Science Digest, Inc., 200 E. Ontario St., Chicago, Ill. (Monthly, $3.00 a year; 25c a copy.)

Science Education, the official organ of the National Association for Research in Science Teaching, the National Council on Elementary Science, and the Science Association of the Middle States. Published by Science Education, Inc., 374 Broadway, Albany, N. Y. (Seven times a year. $2.50 a year; 75c a copy.)

Science News Letter, The Weekly Summary of Current Science, published by Science Service, Inc., 1719 N Street, Northwest, Washington, D. C. (Weekly. $5.50 a year, $10.00 for two years; 15c a copy.)

Scientific American, published by Scientific American, Inc., 24 W. Fortieth St., New York, N. Y. (Monthly, $5.00 a year; 50c a copy.)

The Science Teacher, official journal of the National Science Teachers Association. Published at 201 North School Street, Normal, Ill. (Four times a year. $1.25 a year.)

The Scientific Monthly, publication of The American Association for the Advancement of Science, Washington, D. C. Published by The Science Press, Lancaster, Pa. (Monthly. $7.50 a year; 75c a copy.)

3. OTHER MATERIALS FOR TEACHING SCIENCE

SOURCES OF INFORMATION

This section gives a list of organizations and agencies from which teachers can secure reliable information on various science problems, either free or at a nominal cost. These organizations include commercial companies, scientific societies, museums, and state and United States Government departments and bureaus. Much information on specific problems can be secured also from the community in which one lives.

COMMERCIAL ORGANIZATIONS

Bausch and Lomb, Rochester, N. Y.
Eastman Kodak Company, Rochester, N. Y.
General Electric Company, Schenectady, N. Y.
General Motors Corporation, Research Division, Detroit, Mich.
Metropolitan Life Insurance Company, New York, N. Y.
Taylor Instrument Company, Rochester, N. Y.

MISCELLANEOUS ORGANIZATIONS

American Association for the Advancement of Science, 1515 Massachusetts Ave., N. W., Washington, D. C.
American Chemical Society, Mills Building, Washington, D. C.
American Forestry Association, 919 Seventeenth St., Washington, D. C.
American Home Economics Association, 620 Mills Building, Washington, D. C.
American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.
American Wild Life Institute, Investment Bldg., Washington, D. C.
National Academy of Science, Washington, D. C.
National Board of Fire Underwriters, 58 John St., New York, N. Y.
National Parks Association, 1624 H St., N. W., Washington, D. C.
Science Service, 1719 N St., Northwest, Washington, D. C.
Smithsonian Institution, Washington, D. C.

MUSEUMS

American Museum of Natural History, New York, N. Y.
Buffalo Museum of Science, Buffalo, N. Y.
Carnegie Institute Museum, Washington, D. C.
Chicago Natural History Museum, Chicago, Ill.
Chicago Zoölogical Park, Brookfield, Ill.
Museum of Science and Industry, Chicago, Ill.
Museum of Science and Industry, Rockefeller Center, New York, N. Y.
National Academy of Sciences, Washington, D. C.
National Zoölogical Gardens, Washington, D. C.
New York Botanical Gardens, New York, N. Y.
New York Zoölogical Society, New York, N. Y.

STATE DEPARTMENTS

Agriculture, Fisheries, Forests and Waters, Health, Highways

U. S. GOVERNMENT DEPARTMENTS AND BUREAUS

A list of the publications of these departments and bureaus may be secured from Superintendent of Documents, Washington, D. C.

Sources of Motion-Picture Films

American Museum of Natural History, 79th St. at Central Park West, New York, N. Y. (Rents films on hygiene, domestic science, biology, general science, physics, chemistry.)

Association Films (Y. M. C. A. Motion Picture Bureau), 347 Madison Ave., New York 17, N. Y.

Bausch & Lomb Optical Company, Rochester, N. Y. (Free through local B & L dealers)

Caravel Films, Inc., 245 W. 55th St., New York, N. Y. (Free films on science subjects)

Frank R. Church Films, 829 Harrison Ave., Oakland, Calif. (Sells or rents wild life, industrials, and science subjects. Some are free.)

Commercial Motion Picture Productions, 8634 Sunset Blvd., Hollywood, Calif. (To sell)

Du Pont Company, Motion Pictures Bureau, Wilmington, Del. (Free)

Edited Pictures System, Inc., 330 W. 42nd St., New York, N. Y. (Sells or rents scientific films.)

Encyclopaedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Ill. (Sells and rents Silent Teaching Films, Sound Motion Pictures and Slide films on many science subjects. Now owns large film libraries formerly belonging to Eastman Kodak Company and to Erpi Classroom Films, Inc. For rentals only, write to 207 South Green Street, Chicago, Ill.)

General Electric Company, Educational Service Division, 1 River Road, Schenectady, N. Y. (Rent or free)

Harvard Film Service, The Biological Laboratories, Cambridge, Mass. (Sell or rent sound and silent science subjects.)

Ideal Pictures Corp., 28-34 E. Eighth St., Chicago, Ill.

International Education Pictures, Inc., 40 Mt. Vernon St., Boston, Mass. (Sell or rent; some are free.)

Kodascope Library, 33 W. 42nd St., New York. (Sell or rent.)

Pyrene Manufacturing Co., Sales Promotion Department, 560 Belmont Ave., Newark, N. J. (Free)

School Films Service, Inc., 55 W. 42nd St., New York, N. Y. (Sell or rent science films.)

Society for Visual Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)

Swift & Co., Public Relations Department, Union Stock Yards, Chicago, Ill. (Free)

U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa. (Free)
U. S. Department of Agriculture, Extension Service, Office of Motion Pictures, Washington, D. C. (Free)
The U. S. Office of Education has compiled lists of available films.
United World Films, Inc., 445 Park Ave., New York 22, N. Y. (Now owns large film library formerly belonging to Bell and Howell)
Wild Flowers Preservation Society, 3740 Oliver St., N. W., Washington, D. C. (Sell or rent)
A mimeographed booklet, distributed by the Photographic Section of the Division of Information, U. S. Department of the Interior, Washington, D. C., lists eighty-nine films with brief annotations. Many of these are of science interest. These may be borrowed.

SOURCES OF SLIDES AND FILMSTRIPS

Bray Studios, Inc.. 729 Seventh Ave., New York 19, N. Y.
Chicago Academy of Sciences, Chicago, Ill. (Commercial slides)
General Biological Supply House, 761 E. 69th Place, Chicago, Ill.
General Electric Company, Educational Service Division, Schenectady, N. Y. (Commercial slides)
Keystone View Company, Meadville, Pa.
National Audubon Society, 1000 Fifth Ave., New York 28, N. Y.
National Park Service, Department of Interior, Washington, D. C.
Society for Visual-Education, Inc., 100 E. Ohio St., Chicago, Ill. (Sell or rent many subjects.)
Spencer Lens Company, Buffalo, N. Y.
State Museums. Many lend slides to teachers within their state.
Stillfilm, Inc., Hollywood, Calif.
United States Department of Agriculture, Washington, D. C.
Visual Education Service, Inc., 7024 Melrose Ave., Los Angeles, Calif.
Visual Text [illegible] Company, Los Angeles, Calif.